Rochester Institute of Technology
RIT Scholar Works

Theses | Thesis/Dissertation Collections

11-1-1996

A Study of the relationship between optical dot gain and mechanical dot gain of AM and FM halftones

Eva Gronberg

Follow this and additional works at: http://scholarworks.rit.edu/theses

Recommended Citation
Gronberg, Eva, "A Study of the relationship between optical dot gain and mechanical dot gain of AM and FM halftones" (1996). Thesis. Rochester Institute of Technology. Accessed from

This Thesis is brought to you for free and open access by the Thesis/Dissertation Collections at RIT Scholar Works. It has been accepted for inclusion in Theses by an authorized administrator of RIT Scholar Works. For more information, please contact ritscholarworks@rit.edu.

A study of the relationship between Optical Dot Gain and Mechanical Dot Gain of AM and FM Halftones

by

Eva Joanna Grönberg

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Printing Management and Sciences in the College of Imaging Arts and Sciences of the Rochester Institute of Technology

November 1996

Thesis Advisor: Mr. Franz Sigg

School of Printing Management and Sciences, Rochester Institute of Technology Rochester, New York

---

Certificate of Approval

Master's Thesis

This is to certify that the Master's Thesis of

Eva Joanna Grönberg

With a major in Printing Technology has been approved by the Thesis Committee as satisfactory for the thesis requirements for the Master of Science degree at the convocation of

1996

Thesis Committee:

Franz Sigg
Thesis Advisor

Joseph L. Noga
Graduate program Coordinator

Director of Designate

A study of the relationship between Optical Dot Gain and Mechanical Dot Gain of AM and FM Halftones

I, Eva Joanna Grönberg, hereby grant permission to the Wallace Memorial Library of the Rochester Institute of Technology to reproduce my thesis in whole or in part. Any reproduction will not be for commercial use or profit.

11/20/96

Date

Signature of Author

Acknowledgements

I would like to express my appreciation to the Sweden-America foundation and to Stiftelsen för de Grafiska Yrkenas Främjande who supported my studies at the School of Printing Management and Sciences at Rochester Institute of Technology.

A special thanks goes to first of all my thesis advisor Mr. Franz Sigg of the School of Printing Management and Sciences, RIT for his valuable help, advice and support. I would also like to thank professors Cliff Frazier and Robert Chung of the School of Printing Management and Sciences, RIT.

In addition I would like to thank Neenah paper for supplying the substrate for this study, Mr. Dan Gramlich at the RIT Printing Lab, Mr. David Brydges and Mr. Erwin Widmer of UGRA, St.Gallen, Switzerland.

Moreover I would like to express my gratitude to NSTF and TAGA for their support of this thesis.

Thank You

Table of Contents

List of Figures

List of Tables

Abstract

FM screening differs from conventional screening by the absence of screen ruling and the use of small micro dots to represent the tonal values in an image. FM screens have a high dot gain which is comparable to the dot gain of very fine conventional screens. Some tests showed that FM screens are more stable on press compared to AM screens, that is, they experience less variation in dot gain when the solid ink density is increasing. The major questions of this study were:
1) What is the relationship between mechanical and optical dot gain for FM screens? Is the low dot gain variation of FM screens a consequence of FM screens having a large degree of optical dot gain? 2) What is the relationship between dot size and ink film thickness when printing at increasing solid ink densities? A possible explanation for the stability of FM screened halftone dots could be that they carry less ink than the larger dots in AM screens.

1) A test form with AM and FM screened tone scales was printed on a uniform, translucent, plastic substrate and measured both in transmission and reflectance mode. The substrate that was used in this study is more uniform than paper and will make transmission dot area measurements more accurate. 2) Images of dots of different sizes (21 μm–147 μm), printed at different solid ink densities were captured with a CCD camera. Images from the AM and FM screened tone scales in the test form were also captured with the CCD camera.

It was found that the FM screen was slightly more stable on press than the AM screen, particularly at higher SIDs. The study showed that FM screens have

more optical as well as more mechanical dot gain compared to AM screens. However, the mechanical dot gain of the AM screen increased more when the solid ink density was increasing.

The CCD captures showed that a smaller dot has lower average density (core dot density) than a larger dot. The core dot density of a smaller dot increased less than the core dot density of a larger dot (85 µm or larger) when the solid ink density was increasing. However, the effect of flare is not accounted for, it was not possible in this study to distinguish between core dot density and flare. Flare is light scattering from the substrate areas, causing the average density of the ink to be lower than it actually is.

The study also showed that the average reflectance of the ink and the average reflectance of the substrate is a function of dot area, which explains in part the errors of the Murray-Davies equation.

The stability of the FM screens could be explained by the higher optical dot gain and the lower increase in mechanical dot gain. A possible explanation for the lower increase in mechanical dot gain could be the lower core dot density of the FM halftone dots.

The results are not fully conclusive due to practical problems with the experimental setup, further research has to be done in this area.

Chapter One

Introduction

FM (frequency modulated) screening, or Stochastic screening, was first introduced on the market by Agfa and Linotype-Hell in 1993. FM screening differs from conventional screening by the absence of screen ruling and the use of small micro dots that represent the tonal values in an image. FM screens consist of very small dots of a fixed size (commonly 20–40 µm) and varying spacing instead of dots of varying size and fixed spacing as in conventional screens. Fig.1–4 show images captured with a CCD camera of printed conventional and frequency modulated tints.

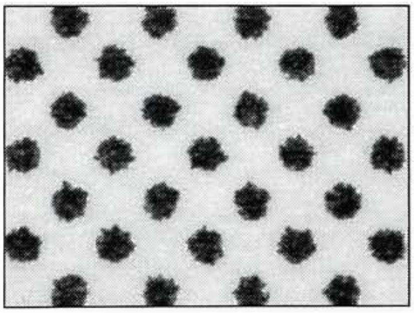


Fig.1 Conventional halftone dots, 22.5% plate dot area, SID 1.2.

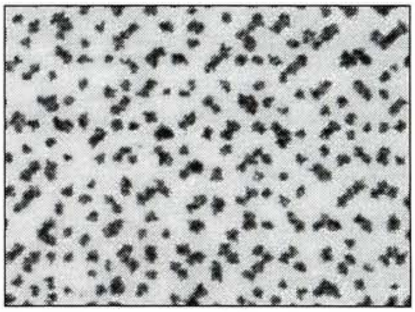


Fig.2 Frequency modulated halftone dots, 22.5% plate dot area, SID 1.2.

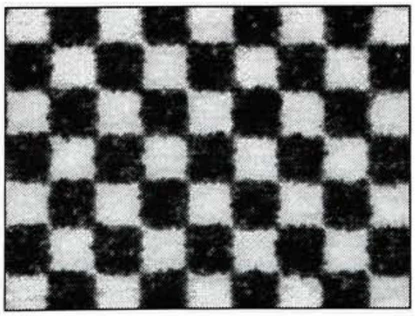


Fig.3 Conventional halftone dots, 54.4% plate dot area, SID 1.2.

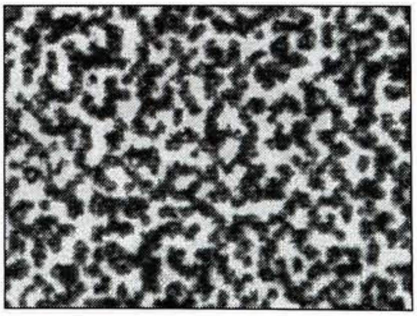


Fig.4 Frequency modulated halftone dots, 54.4% plate dot area, SID 1.2.

Important advantages of FM screening compared to conventional screening are the ability to render finer detail and the elimination of moiré in multicolor printing.

It is commonly known that a finer screen ruling has more dot gain than a coarser screen ruling, it is also known that the dot gain is higher on uncoated stock than on coated stock. Often coarser screens are used in combination with uncoated papers to compensate for the higher dot gain of uncoated stock, this is especially true when printing on newsprint.

The amount of dot gain during printing is affected by changes in solid ink density, and as the solid ink density is increasing the dot gain will also increase. Normally, when dot gain increases the variation in dot gain will also increase.

The amount of dot gain and the variation in dot gain is dependent on the screen ruling, a coarse conventional screen has low dot gain and low dot gain variation. And as the screen ruling increases dot gain as well as the dot gain variation increases. However, it has been observed that very fine screens are less affected than coarse screens by changes in solid ink density. The dot gain variation of extremely fine screens is lower than the dot gain variation of normal conventional screens when printed with increasing solid ink density.

Insensitivity to changes in inking levels was also observed with continuos tone lithography (screen less lithography) in the late 60's and early 70's. The ink-receptive dots in screen less lithography are extremely small, they are defined by the grain structure of the plate[1]. An example of this can be observed when studying printed continuos tone and halftone tints of a UGRA scale (Fig. 5–6). The variation in density of the continuos tone tints is substantially smaller than the variation in density of the halftone tints when the inking levels are increasing.

Fig.5 UGRA scale printed at normal solid ink density.

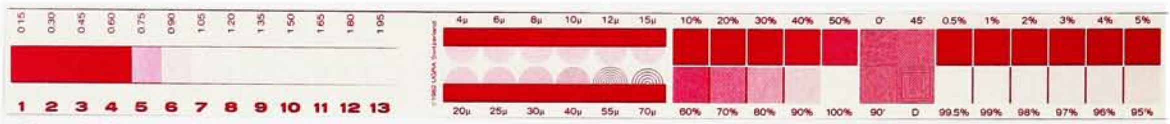


Fig.6 UGRA scale printed at high solid ink density.

FM screens consist of a large number of small micro dots and they have a high dot gain which is comparable to the dot gain of very fine conventional screens. The FM screens tested in an IFRA project[2] had a dot gain of 42–45% when printed on newsprint from negative plates on a non-heat set web offset press. A 200 lpi screen had a dot gain of 40% when printed under the same conditions. The IFRA test also showed that the area of the highest dot gain is shifted from the center towards the 30–40% area for the FM screens. This is also true for fine conventional screens, the finer the screen ruling the more the dot gain curve shifts towards the lower percentages.

Studies[3] have shown that FM screens behave similarly to very fine conventional screens, they have high total dot gain but show a relatively low dot gain variation when inking levels change. Consequently FM images are not as sensitive to changes in solid ink density and are not as subjected to color shifts as conventionally screened images.

Statement of the Problem

The study will look at the relationship between the microdot size of FM screens and the effect of stability when printed with increasing inking levels. How small can a dot be to be reliably handled in prepress? How big can it be before the effect of stability is gone? Which FM dot size is preferred for producing FM halftones in terms of stability?

The study will look at the relationship between mechanical and optical dot gain of frequency modulated and conventional halftones. Mechanical dot gain is affected by changes in solid ink density while optical dot gain primarily depends on the screen ruling and on the translucency of the substrate. A possible explanation for the high dot gain of FM screens could be that it is to a large degree consisting of optical dot gain, which would explain FM screens high dot gain and the lower increase in dot gain when inking levels are increasing.

One explanation for this phenomenon could be that very small dots only can accept a certain amount of ink and not more, and therefore they are more stable.

Endnotes for Chapter One

1. Pearson, M., Pobboravsky, I., "Study of Screen less lithography", TAGA proceedings 1967, pp. 249–262.
2. Schläpfer, K. "Optimal Screening and resolution of digital images for newspapers". EMPA/IFRA project May 25, 1994.
3. Schläpfer, K., Widmer, E. "Are fine screens an alternative to frequency modulation screening?" TAGA proceedings 1994, pp. 34–41.

Chapter Two

Theoretical foundation

The first part of this chapter discusses the background and characteristics of FM screening and the second part covers definitions of dot gain used in this study and factors that influence dot gain.

FM screening

FM screening was first introduced in publications by the Technische Hochschule in Darmstadt in 1983[1]. The term FM (frequency modulated) comes from the field of signal processing, it refers to the way FM screening algorithms construct halftone dots that represent the tonal value in an image. Instead of dots that are evenly spaced and vary in size as in conventional screens, FM screens consist of dots that are uniform in size and vary in spacing. Using the same analogy, conventional screening is referred to as AM (amplitude modulated) screening. The height of the AM waves vary while the spacing is constant which produces dots of different sizes that are equally spaced.

In contrast to conventional halftones, frequency modulated halftones can only be produced electronically. Most of the FM screening algorithms are based on the error diffusion technique[2].

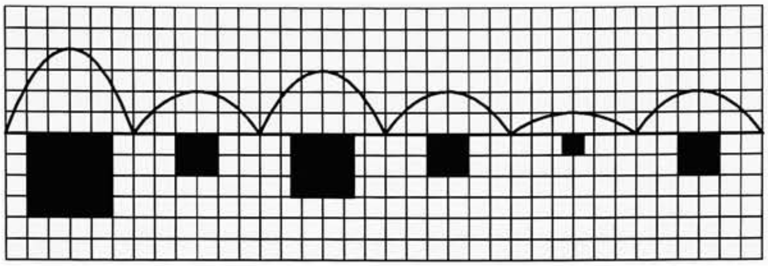


Fig.7 Amplitude modulated (AM) halftone dots, constant frequency.

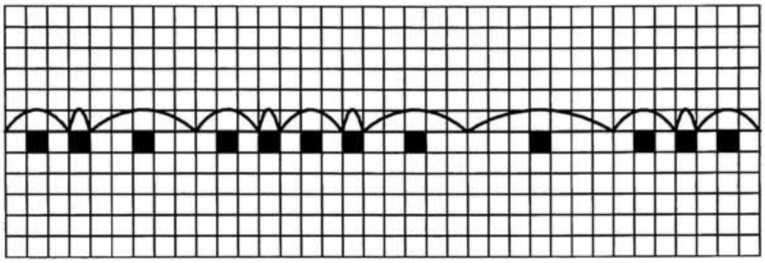


Fig.8 Frequency modulated (FM) halftone dots, constant amplitude.

150 Lines/Inch		
% Dot Area		Dot Diameter
Round dots		Microns
0.5	99.5	13.5
1.0	99.0	19.1
2.0	98.0	27.0
3.0	97.0	33.1
4.0	96.0	38.2
5.0	95.0	42.7
6.0	94.0	46.8
7.0	93.0	50.6
8.0	92.0	54.0
9.0	91.0	57.3
10.0	90.0	60.4
Square dots		
40.0	60.0	107.1
50.0	50.0	119.7

Table 1. Relationship between % dot area and dot diameter, for a 150 lpi AM screen.

Dot size of FM screens

The choice of dot size is an important parameter in FM screening. Dot size determines the quality of the reproduced image, if the dot size is too big it causes a visible grainy structure in the image, and if it is too small, difficulties occur in prepress with transferring the dots to the proof and to the plate.

The screening of images printed with offset lithography is normally produced with high resolution output devices. Halftone dots produced by a single laser spot (usually of the size of 7–10.5 μm) are usually too small to be rendered separately in the printing process, therefore clustered imagesetter dots are produced to obtain a size large enough to be properly rendered.

FM dots for offset lithographic printing are usually constructed of clustered imagesetter spots in groups of 2 x 2 or more, depending on the desired dot size. An imagesetter with an addressability of 2400 dpi has a spot size of 10.5 μm. A FM dot of 21 μm is built up by 2 x 2 of those imagesetter spots. For comparison, a 1% dot in a 150 lpi screen is about 19 μm.

Ability to render finer detail

An important advantage of FM screening is the ability to render finer detail. FM images have the ability to contain more information than AM images. While a dot matrix only contains one AM dot that represents a gray value, the same matrix in a FM image contains several dots that represent the same gray value. In the illustrations below (Fig. 7–8) the 16x16 AM matrix contains one dot while the FM matrix contains 28 dots. Consequently the FM image can contain more information and the limiting factor of the information capacity may be the input scanning resolution. One problem with FM screens however, is the fact that uniform areas look grainier, or have more noise.

AM screened images need a certain imagesetter resolution depending on the screen ruling and the desired number of gray levels to be reproduced. (Gray levels = (Imagesetter resolution/Screen ruling)^2 + 1). A high recording resolution is also needed to smoothly render the edges of the AM halftone dots. The absence of screen ruling and the smaller picture element size of FM halftones makes it possible for FM images to be recorded at a lower output resolution with a quality comparable to an AM image.

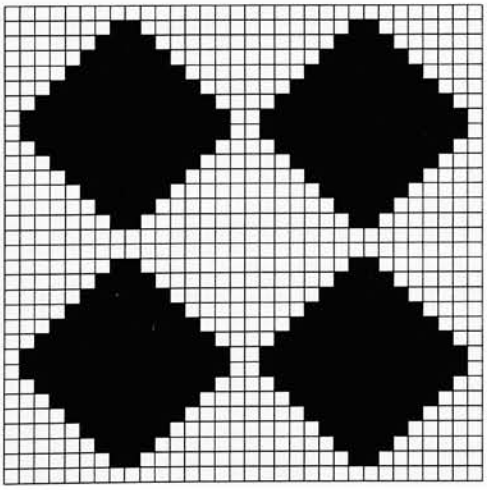


Fig.9 16 x 16 matrices, AM dot, dot area 0.44.

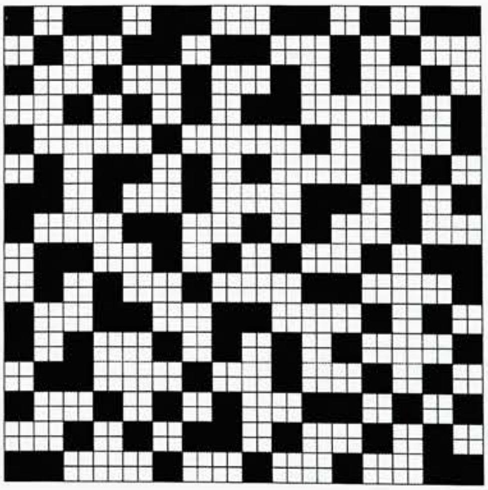


Fig.10 16 x 16 matrices, FM dot, dot area 0.44.

No moiré patterns in multicolor printing

The absence of screen ruling makes FM screening very suitable for printing images using more than four inks. FM screens show no moiré patterns caused by interference of the screen angles in multicolor printing and FM screens also eliminates object moiré, which is caused by interference between the halftone pattern and a pattern in the image. However, when printing large areas of the same gray level FM screens can have the disadvantage of producing a grainy pattern. FM screening is best suited for printing images with a high frequency content, large uniform areas are better reproduced by AM screens.

Proofing and platemaking

A conventional off press proofing system can be used for proofing FM images if the proofing system has high enough resolution. Exposure control is critical to properly render FM images. The most critical part in the reproduction of an FM image is contacting and platemaking, a precise control over the process is necessary to obtain a good result.

There is an advantage of using negative plates for FM screened images. An overexposure of a positive plate will cause the free standing small dots in the highlights to be lost, which would destroy large parts of a FM screened image but have a relatively small impact on an AM screened image. In contrast, when over exposing a negative working plate, only the small free standing dots in the shadows are lost. Loosing small dots in the shadows has a small effect on FM as well as on AM images since the small shadow dots would be filled in when printing anyway.

Dot gain

Dot gain is a term that is widely used in the printing industry but it does not always refer to the same thing. Usually dot gain refers to the difference between the dot area on the film and the resulting printed dot area.

Measuring the physical dot area on paper is complicated. Difficulties occur when measuring the physical dot area on printed sheets, the paper does not have a ideal smooth surface, the ink is not transferred onto the paper in an even layer and halftone dots do not have a well defined edge. Therefore, when speaking of dot gain, it is often the difference between the dot area calculated from reflection density measurements with the Murray-Davies equation and the film dot area that is being referred to.

Murray-Davies equation

The Murray-Davies equation[3] describes a linear relationship between the reflectance of a tint (R_t) and the dot area (a):

$R_t = a \times R_{ink} + (1\text{-}a)\ R_{paper}$

The equation is based on the assumption that the thickness of the ink film covering the halftone dots are the same as the thickness of the inkfilm covering the solids. It is also based on the assumption that reflectance of the ink (R_{ink}) and the reflectance of the substrate (R_{paper}) are the same throughout the tone scale.

In terms of density: $D_t = -\log\ (1-a(1-10^{-D_s}))$ or dot area: $a = (1-10^{-D_t})/(1-10^{-D_s})$

D_t= density of tint

D_s= density of solid

The dot areas calculated by the equation are substantially larger than measured physical dot areas since the Murray-Davies equation does not take into account the effect of light scattering in the substrate. Therefore, dot area calculated by the Murray-Davies equation is often referred to as total dot area, optically effective dot area or equivalent dot area. In this study the term total dot area refers to the dot area calculated from reflection density measurements with the Murray-Davies equation. In this study the term total dot gain refers to the difference between the total dot area and the plate dot area.

Optical dot gain (the Yule-Nielsen effect)

Yule and Nielsen[4] studied the effect of light penetrating and scattering in the substrate. Light that enters between the printed dots in a translucent paper surface will spread sideways within the substrate and some of the light gets trapped underneath the halftone dots. The light goes through multiple internal reflections[5] before it emerges from the substrate. This will cause a printed 50% tint to absorb more than 50% of the incoming light and the halftone dots appear to be larger than they actually are.

A good term to label this phenomenon would be the Yule-Nielsen effect. However, the less descriptive term optical dot gain has found widespread use in the industry and is also used in this study. The term optical dot gain refers to the increase in optical density due to the effect of light penetrating the substrate.

Yule and Nielsen suggested the incorporation of a n-factor in the Murray-Davies equation. The empirically derived n-factor corrects for the amount of light that is spread in the substrate and trapped underneath the halftone dots. The n-factor depends primarily on the spacing of the dots and on the translucency of the substrate.

The Yule-Nielsen equation:

$D_t = -n \log (1-a(1-10^{-D_s/n}))$ or $a = (1-10^{-D_t/n})/(1-10^{-D_s/n})$

a= dot area

D_t= density of the tint

D_s= density of the solid

A value of n=1 will reduce the Yule-Nielsen equation to the Murray-Davies equation, which means that no spreading of light in the substrate is taken into account when calculating dot area. This could be the case when calculating the dot area for a very coarse screen where the effects of light spreading in the substrate are negligible or when calculating the dot area for a printing plate where light can not penetrate the surface. A higher value of n represents increasing spreading of light in the substrate, which will increase with the use of finer screen rulings.

The type of substrate will also affect the n value, an uncoated paper is more translucent than a coated paper and more light penetrates the surface and spreads in the uncoated paper.

The n-factor in the Yule-Nielsen equation is typically between 1 and 2. Pearson[6] suggested the use of a n value of 1.7 when printing on coated stock with a 150 lpi screen.

After Yule and Nielsens study there have been several other theories and models proposed for the effect of light spread in the substrate on halftone printing[7,8,9,10].

Mechanical dot gain

Mechanical dot gain (dot spread) is referred to as the change in the physical area of the halftone dot. Mechanical dot gain is the change in dot area that occurs when the dot is transferred from the film to the plate, from the plate to the blanket and from the blanket to the substrate. Factors that influence mechanical dot gain are: plate exposure and processing, type of blanket, packing of blanket and impression cylinder, pressure, inking level, ink viscosity, fountain solution, type of press, press speed etc. The changes in dot area throughout the offset printing process have been investigated by Takahashi (et al)[11]. The study showed that the largest increase in dot area took place between the plate and the blanket cylinder and a small or no gain occurred between the blanket cylinder and the substrate.

There are several theories proposed for calculating mechanical dot gain. The Border zone theory assumes 1) the dot gain occurs at the edge (border zone) of a dot, 2) that all dots undergo a constant increase in diameter. Studies[12,13] indicate that this does not hold true for the smaller dots. The dots in the highlights undergo a lower increase in diameter than the dots in the midtones and in the shadows. Another proposed theory is the Perimeter model which holds that the increase in diameter is proportional to the perimeter of the halftone dot. The GRL dot gain model of Viggiano[14] was derived empirically to fit the general shape of typical dot gain curves, and it is a compromise solution between these two theories.

Measuring mechanical dot gain in transmission mode

Another method of obtaining a measure of mechanical dot gain of printed halftone dots is measuring dot area in transmission mode. Measurements through the substrate will not be affected by sideways scattering of light which causes optical dot gain. They will only take into account the change in physical dot area and the change in density of the halftone dots. When measuring printed halftones in transmission mode, the instrument first needs to be zeroed on an unprinted area of the substrate. The substrate has to be uniform in transmission to give reliable results or the variation in transmission can be statistically averaged by using a large number of samples. A method of measuring transmission dot area of halftones printed on paper was developed by Frøslev-Nielsen[15] in 1967, it requires a sample size of 100 to give a good estimate of the physical dot area.

Measurements of total, mechanical and optical dot gain.

Halftone scales can be printed on a uniform plastic translucent substrate and measured both in transmission and reflectance mode.

1) A measure of total dot gain is obtained by converting the reflection density measurements to dot area with the Murray-Davies equation.

2) A measure of mechanical dot gain is obtained by measuring dot area in transmission mode. The instrument is zeroed on the substrate.

3) A measure of optical dot gain is obtained by subtracting the mechanical dot gain from the total dot gain.

Endnotes for Chapter Two

1. Fischer, G. dissertation: *"The frequency modulated image composition – a contribution to the optimization of print quality."* Darmstadt, 1986.

2. Floyd, R. W. , Steinberg, L. *"An Adaptive Algorithm for Spatial Grey Scale"* SID 75 Digest. Society for Information Display, 1975 pp. 36–37.

3. Murray, A. *"Monochrome Reproduction in Photoengraving"* J. Franklin Inst. 221, 1936.

4. Yule J.A.C, Nielsen W.J *"The penetration of light into paper and its effect on halftone reproduction"* TAGA proceedings, 1951.

5. Clapper F.R., Yule J.A.C *"The effect of Multiple Internal Reflections on the Densities of Halftone Prints on Paper"*, Journal of the Optical Society of America, July 1953, pp. 600–603.

6. Pearson, M. *"n value for general conditions"*, TAGA proceedings, 1980 pp. 415–425

7. Brune, M., Pauckner, L. *"Influence of internal light scattering on halftone printing."* IARIGAI Proceedings, 1977, pp.109–119.

8. Huntsman, J.R. *"A new model of dot gain and its application to a multilayer color proof"*, Journal of Imaging Technology, Volume 13, Number 5, 1987.

9. Kruse, B. , Wedin, M. *"A new approach to dot gain modeling"*, TAGA proceedings, 1995, pp. 329–338.

10.. Arney, J.S., Engeldrum, P. G., Zeng,H. *"A modified Murray-Davies model of halftone gray scales"*, TAGA proceedings, 1995, pp.353–363.

11. Takahashi, Y. , Fujita, H. , Sakata, T. *"Ink Transfer and Dot Gain Mechanisms in Offset Printing Process"* Bulletin of the Technical Association of the Graphic Arts of Japan, Vol 21, No.3, 1983 p.22–32.

12. Yule, J., *"Variation of tone reproduction in halftone processes"*, Printing Inks and Color, IARIGAI proceedings 1953, pp. 48-66.

13. Sigg, F., *"A new densitometric quality control system for offset printing"*, TAGA proceedings 1970. pp.197–213.

14. Viggiano, J. A .S *"The GRL Dot Gain Model"*, TAGA proceedings, 1981, p.423–439.

15. Frøslev-Nielsen., *"Some comments on the formulation and determination of dot area in halftone prints on paper"*, Inks, plates and print quality, Proceedings of the Ninth International Conference of Printing Research Institutes, Rome 1967, pp. 141–155.

Chapter Three

Review of Literature

Dot gain of FM screens

Tests described in a paper from 1994 by Schläpfer and Widmer[1] showed that FM screens have lower dot gain variation compared to conventional screens when inking levels were increasing. When the solid ink density was increased by 0.2 units, the dot gain observed with the FM screens was 3–4 % higher in the midtones, while a conventional halftone screen of 150 lpi showed a 6% increase.

> "A theoretical explanation for this phenomenon does not yet exist. Printing of FM screens seems to have a similarity with screenless printing where the plate grain plays the role of ink-receptive microdots. Also in screenless lithography a low sensitivity to variations of the ink film thickness can be observed. An explanation for this could be that the classic dot spread occuring in the printing nip is eliminated when the printing elements have a size comparable with the plate grain. This situaton is almost reached for FM screens, because the printing dots are not much larger than the size of the ink-receptive elements in screenless lithography. This theory is also in line with reports that extreme fine screens exceeding 180 lines/cm show a similar behavior."

In Laoharavees[2] independent study at RIT 1995, AM and FM tints were printed at varying inking levels. At low inking levels the AM and FM tints looked the same, at high inking levels the AM tints filled in while the FM tints were less affected. Filling in or plugging occur when printing with too high inking levels, this indicates that FM screens have less mechanical dot gain than AM screens.

Relationship between dot area, dot density and ink film thickness

In a paper of Yule[3] he states four factors that affect the relationship between dot size and tint density:

1) solid ink density

2) dot-size variation

3) penetration of light into paper

4) variation in ink film thickness

The most important factor is the solid ink density. The second factor is the change in dot area which occurs in platemaking and printing (mechanical dot gain). The third factor is the effect of light penetrating into the substrate (optical dot gain). For the fourth factor Yule mentions the possibility that the halftone dot does not have the same ink film thickness as the solid. Also in their 1951 TAGA paper[4] Yule and Nielsen stated that; "It is not certain that the small dots carry as heavy a layer of ink as the solid".

The relationship between dot area and inkfilm thickness has been investigated in several studies. In a study by Brune and Pauckner[5] they conclude that the thickness of the ink film transferred by lithographic printing varies with dot size.

> "The density values of single printed elements in offset printed halftones are not identical with the solid ink density as normally assumed, but become smaller with decreasing dot size. This was demonstrated by measurements with a reflection-microdensitometer."

Therefore, if a variable ink film thickness does exist, the tone reproduction in the shadows would be altered more than the tone reproduction in the highlights, because the shadows are covered with larger dots which would carry a thicker layer of ink than the dots in the highlights. This could be part of the explanation of why FM screened images are less affected than AM images by changes in solid ink density.

Many studies point out the possibility of smaller dots having a thinner ink layer than larger dots. Many studies have also investigated the difference between optical and mechanical dot gain of printed halftones. This study is looking at the relationship between optical and mechanical dot gain of small halftone dots (FM screened halftones) and in addition it is investigating the relationship between dot size and inkfilm thickness of small halftone dots.

Endnotes for Chapter Three

1. Scläpfer, K., Widmer, E. "Are fine screens an alternative to frequency modulation screening?", TAGA proceedings 1994, pp.34–41.
2. Laoharavee, T., *"Optimzing Tone Reproduction for AM and FM halftones to print at normal and high density levels"*, Independent study, RIT, 1995.
3. Yule, J., *"Variation of tone reproduction in halftone processes"*, Printing Inks and Color, IARIGAI proceedings 1953, pp. 48-66.
4. Yule J.A.C, Nielsen W.J *"The penetration of light into paper and its effect on halftone reproduction"* TAGA proceedings, 1951.
5. Brune,M., Pauckner, L. *"Influence of internal light scattering on halftone printing."* IARIGAI Proceedings, 1977, pp.109–119.

Chapter Four

Hypothesis

The major questions of this study are: 1) What is the relationship between mechanical and optical dot gain of FM screens? Is the low dot gain variation of FM screens a consequence of a higher amount of optical dot gain? 2) What is the relationship between dot size and ink film thickness (dot density) when the inking levels are increasing?

Statement of Hypotheses

H1: When printed at low solid ink density by offset lithography on a translucent substrate, FM screened tone scales will have higher total dot gain than AM screened tone scales when measured in reflection mode (Murray-Davies equation).

H2: When printed at low solid ink density by offset lithography on a translucent substrate, FM screened tone scales will have the same dot area (± 2% dot area at the midtones) as AM screened tone scales when measured in transmission mode.

Low SID		High SID	
Reflection mode	**Transmission mode**	**Reflection mode**	**Transmission mode**
FM looks darker than AM because FM has more optical dot gain than AM.	FM and AM look the same because the optical dot gain has no effect in transmission mode and there is no difference in mechanical dot gain when printing at low SID.	FM and AM may look the same, since AM has more mechanical dot gain and FM has more optical dot gain. This will be a function of SID and tint dot area.	AM looks darker than FM because AM has more mechanical dot gain than FM.
Hypothesis 1	**Hypothesis 2**	**Hypothesis 3**	**Hypothesis 4**

Fig 11. Summary of assumptions for hypotheses.

H3: When printed at high solid ink density by offset lithography on a translucent substrate, FM screened tone scales will have the same dot area (± 3% dot area at the midtones) as AM screened tone scales when measured in reflection mode.

H4: When printed at high solid ink density by offset lithography on a translucent substrate, FM screened tone scales will have lower dot gain than AM screened tone scales when measured in transmission mode.

Limitations

1. Assume no directional dot gain.
2. Assume even ink layer applied to the tone scales on the press sheet.

Delimitations

1. Two screens will be investigated: AM screen–Agfa Balanced screening (150 lpi square dot), FM screen–Agfa Cristal Raster, (21 µm dot size).
2. The hypotheses will be tested at the dot areas: 5.5%, 11.5%, 22.5%, 33.7%, 44.4%, 54.4%, 64.4%, 73.4%, 83% and 92% (plate dot area).
3. The test form will be printed with black ink at low SID = 0.9, high SID = 1.2, 1.6, 1.9 and 2.1.
4. Press variabilities are not investigated.

Research Questions

The study will look at the relationship between the microdot size of FM screens and the effect of stability when printed with increasing inking levels . How small can a dot be to reliably be handled in prepress? How big can it be before the effect of stability is gone?

In FM screens there are not only free standing dots. Depending on the FM algorithms that are used, the dots start to cluster at different tonal areas (often around the 20% area). How are different tonal areas affected when inking levels are changed? The solid and shadow areas are obviously affected by changes in inking levels while the highlights will not be affected to the same degree.

Is there a difference in inkfilm thickness between small and large halftone dots?

Chapter Five

Methodology

The first objective was to investigate the difference in tone reproduction due to changes in inking levels when using different screening technologies. What is the relationship between optical and mechanical dot gain when printing FM and AM screens at increasing inking levels? The second objective was to study the relationship between dot size and dot density when printing with increasing inking levels. Is there a difference in ink film thickness of small and large dots?

Experimental procedures

In order to differentiate between mechanical and optical dot gain a test form was printed on a uniform translucent plastic substrate. Density measurements were taken in reflection mode and dot area measurements were taken in transmission mode of the AM and FM tone scales printed on the test form.

The test form

The test form contains the following elements:

1) Tone scale with tint patches 5%, 10%, 20%,30%, 40%, 50%, 60%, 70%, 80%, 90%, 100%, screened at 150 lpi with Agfa Balanced Screening, **2)** Tone scale with tint patches 5%, 10%, 20%,30%, 40%, 50%, 60%, 70%, 80%, 90%, 100% screened with Agfa Cristal Raster,

Pixeldot target

Clustered imagesetter spots

	Dot size
1x1 spot	10.5 µm
2x2 spot	21 µm
3x3 spot	32 µm
4x4 spot	42 µm
5x5 spot	53 µm
6x6 spot	63 µm
7x7 spot	74 µm
8x8 spot	84 µm
9x9 spot	95 µm
10x10 spot	105 µm
11x11 spot	116 µm
12x12 spot	126 µm
13x13 spot	137 µm
14x14 spot	147 µm
15x15 spot	158 µm

Fig.12 The Pixeldot target, clustered imagesetter spots vs. dot size.

dot size 21 µm, **3)** Pixeldot test target, a target containing dots of different sizes constructed by clustered imagesetter spots. The size of the Agfa SelectSet 5000 imagesetter 1x1 spot is 10.5 µm, the dots in the target range in size from 10.5 µm (1x1 spot) to 158 µm (15x15 spots). The Pixeldot target contains the clustered imagesetter dots at five different dot areas: 0.111, 0.25, 0.5, 0.75 and 0.889. **4)** The digital UGRA wedge, **5)** The RIT Digital Output Resolution tester which contains among other items lines of the width of one image setter spot (10,5 µm) to lines of the width of 4 imagesetter spots (42 µm), **6)** UGRA PCW (for plate exposure control), **7)** Print control bar containing tint patches 25%, 50%, 75% and solids, **8,9,10)** Pictorial b/w images (high key, low key, high frequency, low frequency, flesh tones), screened with Agfa Balanced Screening (150 lpi), **11,12,13)** Pictorial b/w images (high key, low key, high frequency, low frequency, flesh tones), screened with Agfa Cristal raster (21µm). Fig. 11 shows the design of the test form.

The test form was output on the Agfa SelectSet 5000 imagesetter using Agfa Alliance film and processed with rapid access chemistry. Platemaking was done in the T&E center using 3M Viking high resolution plates, using a low exposure resulting in a solid step 1 on the UGRA Plate Control Wedge. The low exposure was chosen to minimize mechanical dot gain at the platemaking stage. A transfer curve was

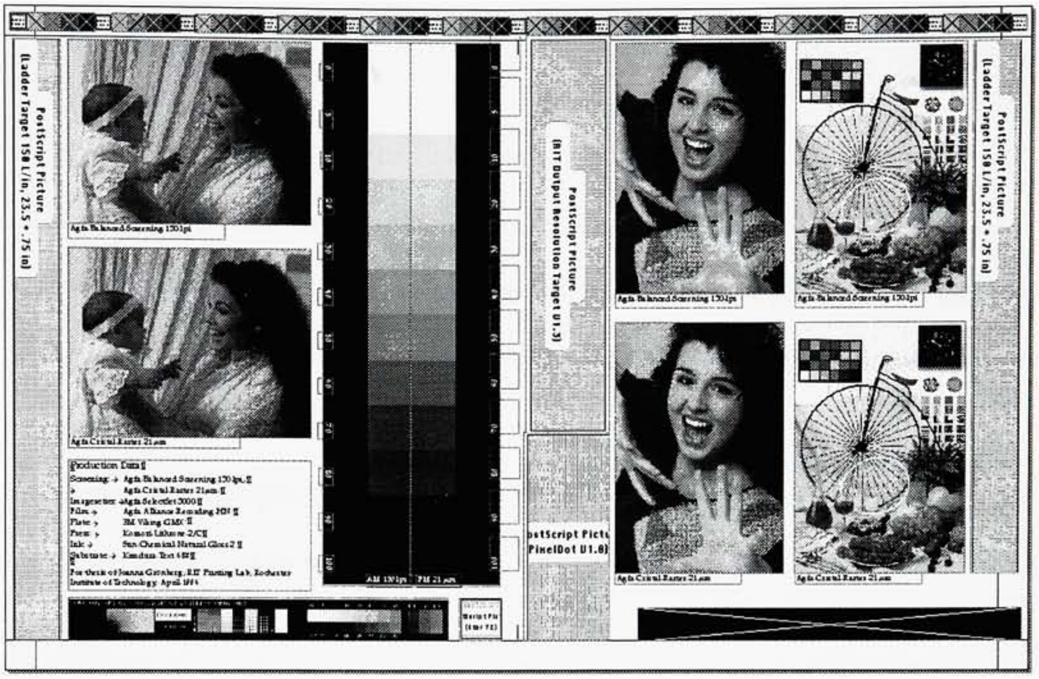


Fig.13 The test form, size: 17" x 11"

applied to the FM tone scale and to the FM images to produce the same dot areas on plate as the AM tone scale, the desired plate dot areas were verified with densitometer readings.

The test form was printed on Kimdura #68 with black ink, Sun Chemical Natural Gloss 2, using the Komori Lithrone 2/C press at the RIT Printing Lab. The pressrun started out with a low solid ink density (SID= 0.9) and after that the test form was printed at increasing inking levels (SID= 1.2, 1.35, 1.6, 1.9, 2.1). The number of sheets available for this print-run was limited to 500 and make-ready was done on another substrate (coated offset paper). The substrate was switched when the desired solid ink densities were reached. There were difficulties in achieving the desired aim values due to differences in inking levels which is reflected in the results as experimental variability.

Data collection: reflection and transmission measurements of AM and FM tone scales

The printed tone scales with tint patches screened at 150 lpi and 21µm was first measured with a reflection densitometer, the density readings was converted to % dot area calculated by the Murray-Davies equation. The tone scales were then measured with a transmission dot area meter, (the light absorbed by the ink film is proportional to the % dot area).

A measure of optical dot gain was obtained by subtracting the total dot gain (measured in reflection mode) from the mechanical dot gain (measured in transmission mode).

Data collection: measurements of inkfilm thickness and dot density of halftone dots in the Pixeldot target

The second part of this study was to investigate the difference in ink film thickness of small and large dots, and also to investigate the change in ink film thickness of small and large dots when the inking levels are increasing.

Measurements of ink film thickness with an Atomic force microscope

An attempt was made to obtain a physical measure of the ink film thickness on solids vs. halftone dots. An atomic force microscope, which is an instrument that allows examination of surfaces at high magnification and resolution, was used to measure the halftone dots in the Pixeldot target. The instrument used in this study can scan an area of maximum 100 x 100 µm and can measure differences in height at a resolution of 0.01 nanometers.

> "The instrument uses a cantilever mounted probe of silicon nitride shaped like a pyramid or a very fine conical tip attached to the apex of the pyramid. As the probe is scanned across the specimen, the vertical motion of the cantilever is measured by the use of a laser beam reflected from it onto a four quadrant photo detector. This allows the software to measure both lateral force and the vertical motion by means of combining the output of each of the four quadrants in different ways."[2]

The attempt was not successful because the unevenness of the substrate used in this study was much higher than the difference between the inked and non-inked areas. See Appendix B. Instead a microscope with a CCD camera was used to investigate the relationship between dot size and dot density.

Measurements of dot density in relation to dot size.

Images of the dots in the Pixeldot target (dot sizes ranged from 10.5µm–147µm) were captured with a CCD camera. The average density of small vs. large dots printed at different inking levels was recorded. The images were captured using a Sony 3 CCD Color video camera onto a RasterOps frame grabber. Image field of view was 1 x 0.75 mm, digitized at a pixel resolution of 640 x 480 pixels. (1 pixel=1.56 µm, 13.4 x 13.4 pixels per 2 x 2 imagesetter spots).

The camera was calibrated against known reflectance values and the pixel values from the camera were linear with respect to the reflectance standard. Fig.12. The reflectance standard was a continuos tone grayscale and the measured samples are halftones, therefore errors in the measurements will occur due to flare. A good way of correcting for this could not be found, in this study the uncorrected data is

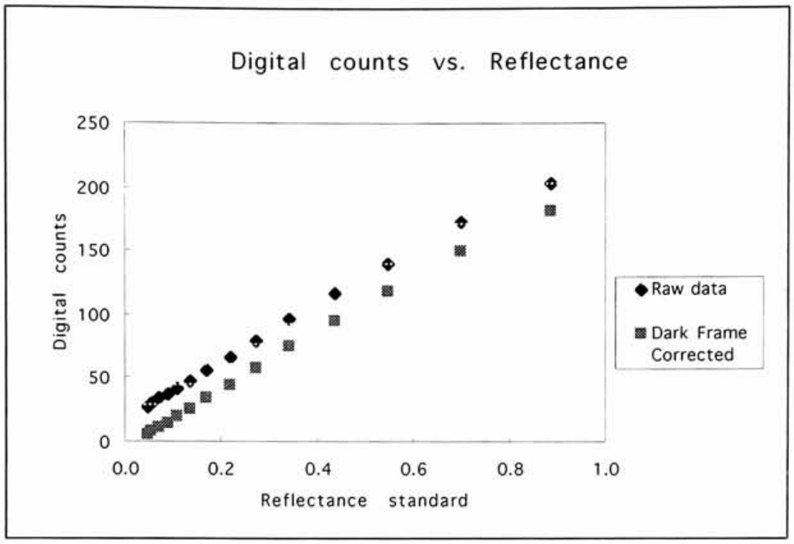


Fig.14 Digital counts from the CCD camera linear with respect to a reflectance standard.

used knowing that the high densities measured from the halftone tints are probably somewhat lower than they should be.

The reflectance data was collected from the reflectance distribution, histogram, in Photoshop. The two peaks in the histogram correspond to the average reflectance of the ink (R_{ink}) and to the average reflectance of the substrate (R_{sub}) between the halftone dots. The central pixel value from peak of the ink distribution

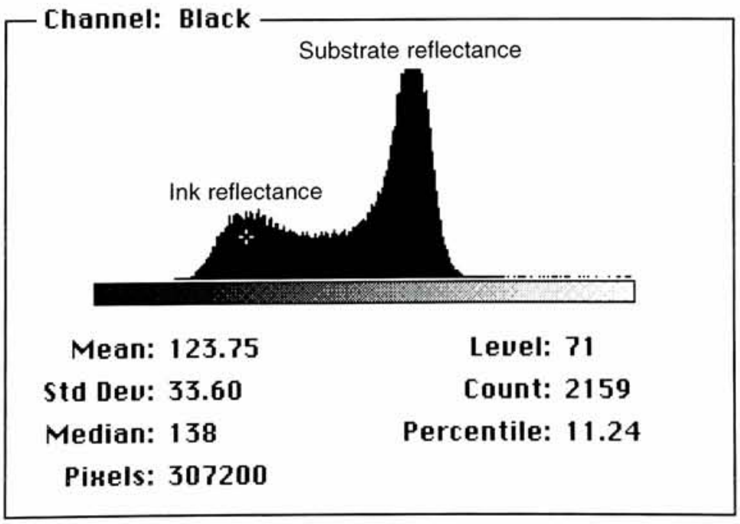


Fig.15 Reflectance distribution, the two peaks in the histogram correspond to the average reflectance of the ink (Rink) and to the average reflectance of the substrate (Rsub) between the half-tone dots, Pixeldot target, dot size 32µm dot, dot area 0.25, SID 1.2. Pixel value for R_{ink}: 71.

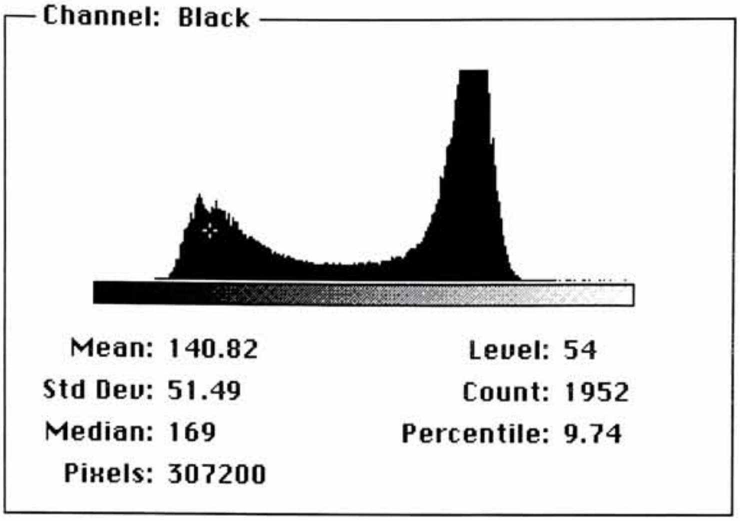


Fig.16 Reflectance distribution, Pixeldot target, dot size 85μm dot, dot area 0.25, SID 1.2. Pixel value for R_{ink}: 54.

was chosen subjectively from the histogram. The shape of the reflectance distribution of the ink changes with dot size. Fig.13–14. Difficulties occur in choosing the central pixel value for the smaller dots due to the less distinct peak of the ink reflectance distribution. The pixel value was then converted to reflectance by calibration against a white reference (the unprinted substrate) and against a dark frame (image captured with the lens cap on).

The reflectance values were then converted to density, in this study referred to as core dot density. Core dot density is a measure of the average density of the inked areas. The core dot density was recorded for the dot sizes: 21μm, 32μm, 42μm, 63μm, 84μm, 105μm, 126μm and 147μm, at 25% dot area, from the Pixeldot target, printed at SID: 0.9, 1.2, 1.6 , 1.9 and 2.1.

Measurements of the reflectance of the ink and the reflectance of the substrate in relation to dot area.

Images were also captured with the CCD camera from the AM and FM screened tone scales in order to investigate how differences in dot area affected the average reflectance of the inked areas and the average reflectance of the substrate. The images were captured under the same conditions as previously described and the average reflectance data of the inked areas and the average reflectance data of the

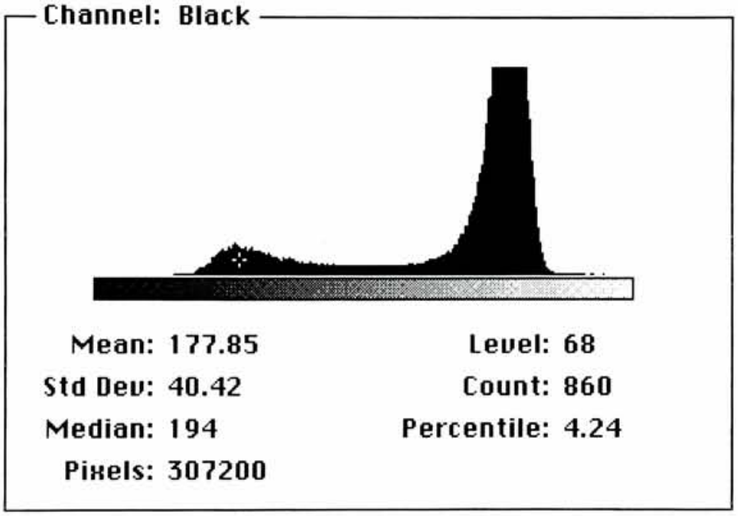


Fig.17 Reflectance distribution, AM tint, dot area 0.117, SID 1.2. Pixel value for R_{ink}: 68

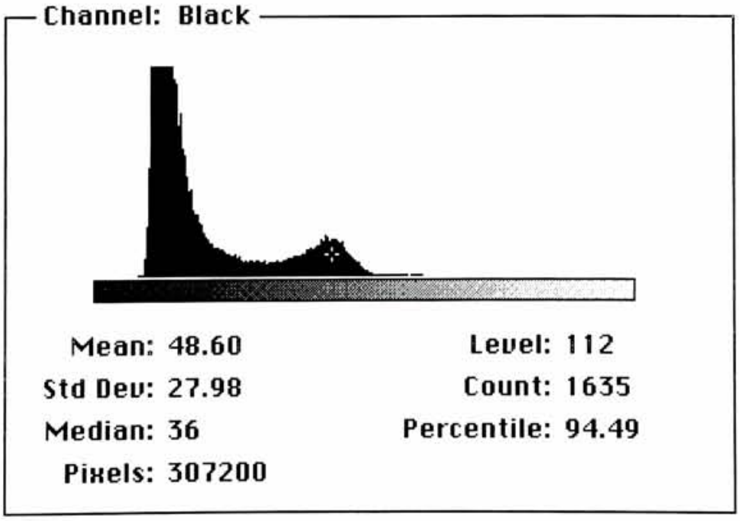


Fig.18 Reflectance distribution, AM tint, dot area 0.834, SID 1.2. Pixel value for R_{sub}: 112

substrate was collected from the histogram in Photoshop. Difficulties occur in choosing the central pixel value of the ink reflectance distribution for the lower dot areas due to the less distinct peak of the ink distribution. Fig.15. Similarly difficulties occur in choosing the central pixel value of the substrate reflectance distribution for the higher dot areas due to the less distinct peak of the substrate distribution. Fig.16. Images were captured at all dot areas of the AM and FM tone scales, for SID: 1.2, 1.6 and 1.9.

Equipment and Materials

Prepress:

Computer:	Apple Power Macintosh 8100/80
Software:	Adobe Photoshop 3.0, QuarkXPress 3.31, Adobe Illustrator 5.5
Screens:	Agfa Balanced screening 150 lpi (square dot)
	Agfa Cristal Raster 1.0, 21 µm spot size
Imagesetter:	Agfa SelectSet 5000, 2400 dpi (10.5 µm spot size)
RIP:	Agfa 5000PS Star plus RIP
Film:	Agfa Alliance GS 712 HN
Processor:	Agfa Rapiline26, Rapid Access chemistry

Press:

Plates:	3M Viking GMX
Press:	Komori Lithrone 2/C, RIT Printing lab

Substrate: Kimdura Text 68#

Ink: Sun Chemical Natural Gloss 2

Data collection:

Reflection density measurements: X-Rite 938 Spectro densitometer, black backing

Transmission dot area meter: custom built by Franz Sigg, RIT.

Microscope: Stemi SV11, Zeiss Germany

CCD camera: Sony 3CCD Color video camera, Model DXC-930P

Software: RasterOps frame grabber, Adobe Photoshop 3.0

Endnotes for Chapter Five

1. Frøslev-Nielsen., *"Some comments on the formulation and determination of dot area in halftone prints on paper"*, Inks, plates and print quality, Proceedings of the Ninth International Conference of Printing Research Institutes, Rome 1967, pp. 141–155.
2. Bassemir R., Costello G., Parris J.,*"An investigation of ink, coating and substrate surfaces using atomic force microscopy"*, TAGA proceedings 1995, pp. 876–893.

Chapter Six

Results and Findings

Total dot gain of AM and FM screens.

Reflection density measurements were taken from the tints in the AM and FM tone scales and converted to dot area using the Murray-Davies equation. Fig.19–20 show that FM tone scales have more total dot gain than AM tone scales. As the solid ink density increases the dot gain increases and the peak of the dot gain curve shifts towards the lower dot areas (0.3-0.4).

The increase in total dot gain when printing at SID 1.2 and increasing to SID 1.6 is slightly lower for the FM screen. At dot area 0.44, the dot gain of the FM screen increases 4,5% (from 23.4%–27.9%) and the dot gain of the AM screen increases

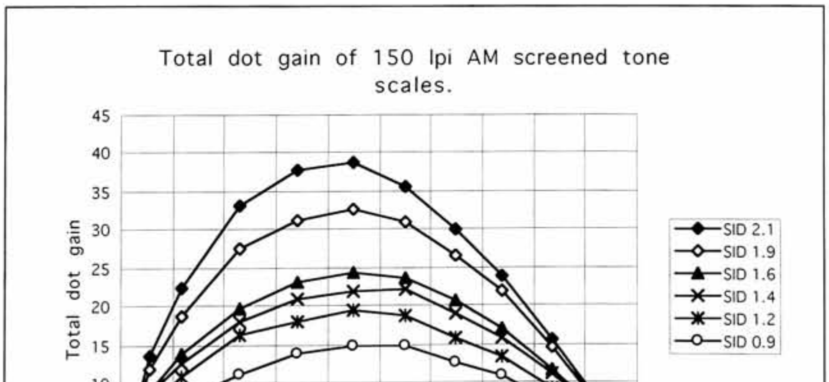


Fig.19 Total dot gain, AM 150 lpi.

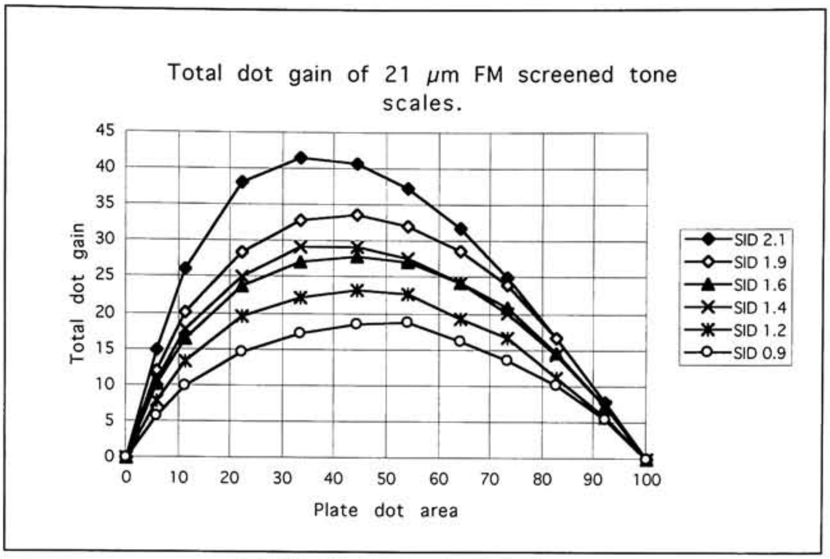


Fig.20 Total dot gain, FM 21µm.

5.0% (from 19.6%–24.6%). Note that in the following figures,the indicated solid ink densities are the nominal values. See Table A.7 in Appendix A, for the measured values of the solid ink density.

Note that for the FM tone scale, the sheet with a solid ink density of 1.4 has more total dot gain than the sheet with a solid ink density of 1.6. However, this is not the case for the AM tone scale as seen in Fig.19. The sheet with a SID of 1.4 is assumed not to be representative of the other sheets, and therefore it is not included in the rest of the figures in this chapter. The reason for excluding SID 1.4 is because of the unstable printing conditions. The make-ready was done on coated stock due to the limited number of of Kimdura sheets available. After the press had reached the desired inking level the substrate was switched to Kimdura. Unfortunately this resulted in variations in inking between the sheets which is reflected in the results as experimental variability. Therefore, these graphs are to be seen as an indication of a general trend and not as fully conclusive.

Mechanical dot gain of AM and FM screens

Transmission dot area measurements were taken from the tints in the AM and FM tone scales. The dot area is equal to the amount of light absorbed by the tint divided by the amount of light absorbed by the solid. This is a measure of the physical dot area assuming that the same amount of light is transmitted through the ink film of the solid and of the halftone dots. Another assumption is that the base of the sub-

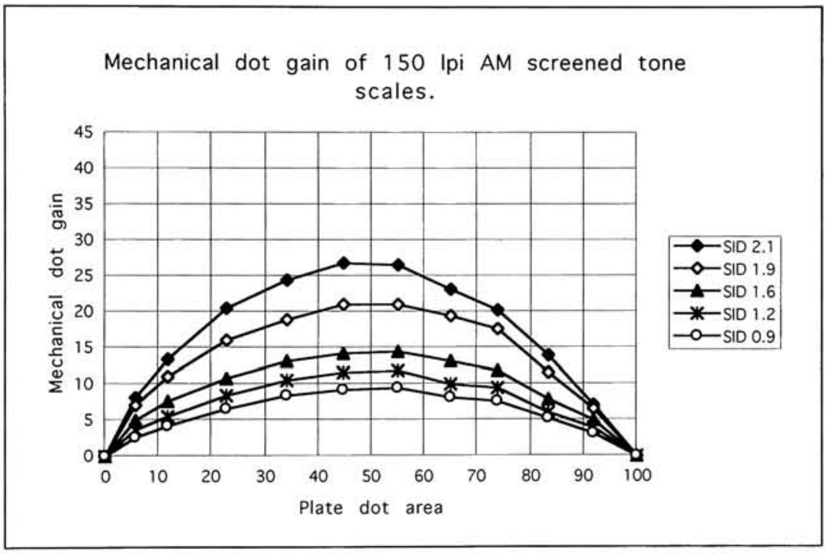


Fig.21 Mechanical dot gain, AM 150 lpi.

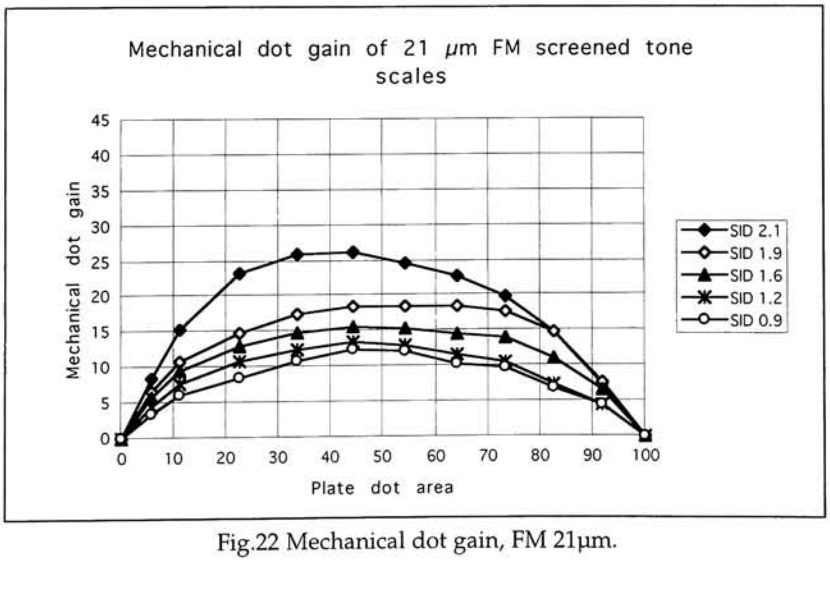


Fig.22 Mechanical dot gain, FM 21μm.

strate will transmit the same amount of light at the area where the instrument is zeroed and at the area where the measurements are taken. To evaluate the evenness of Kimdura, transmission dot area measurements through the base of seven sheets were taken. A maximum variation of 0.6% dot area within a 20 x 20 mm area was found. (Table A.7 in Appendix A).

The FM screen has 2–3% higher mechanical dot gain at the midtone dot areas than the AM screen for low and normal solid ink densities (SID 0.9, 1.2, 1.6). Fig.21–22. However, the increase in mechanical dot gain due to increasing SID is almost the same for the tints in both the AM and the FM tone scale. It was expected that the FM tints should have a lower increase in dot gain than the AM tints which also was the case, however the difference was so small that it is within experimental error. At dot area 0.44, and SID 1.2–1.6, the dot gain of the FM screened tint increases 2.2% (from 13.4%–15.6%) and the dot gain of the AM screened tint increases 2.6% (from 11.7%–14.3%).

A tendency towards larger difference in mechanical dot gain can be observed at higher solid ink densities. At high solid ink densities (1.9, 2.1) the mechanical dot gain of the AM screened tone scales is higher than the mechanical dot gain of the FM screened tone scales (for dot areas 0.44, 0.54, 0.64). At SID 1.9 and dot area 0.44, the AM tint has a mechanical dot gain of 21.1% and the FM tint has a mechanical dot gain of 18.6%. On the other hand, at the density of 2.1, the difference between the AM and FM screen is much smaller. This is another example of variability of the press run.

Optical dot gain of FM and AM screens

A measure of the optical dot gain is obtained by subtracting the mechanical dot gain from the total dot gain. Fig.23–24 show that optical dot gain is a function of solid ink density, the optical dot gain is highest in the quarter tone and midtone areas. The peaks of the AM and the FM curves shift toward the lower percentages when the solid ink density increases. With increasing solid ink density the optical dot gain increases more in the quarter tone and midtone areas than in the shadows.

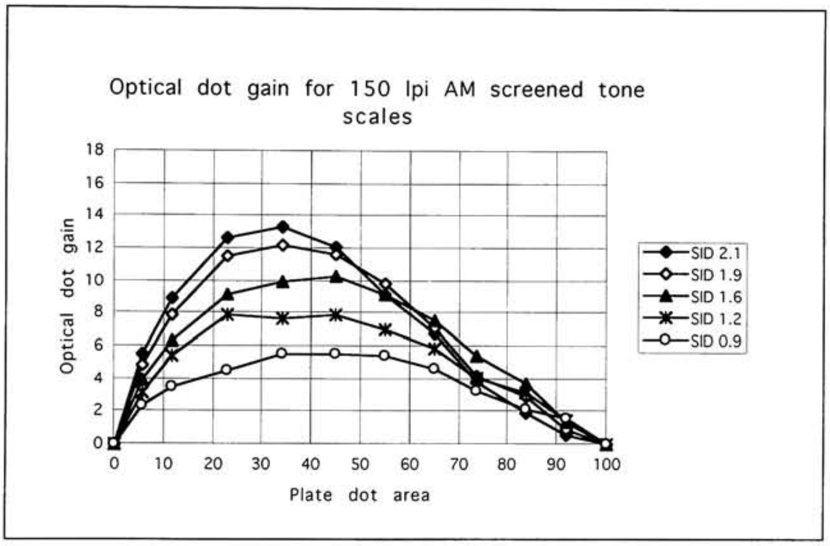


Fig.23. Optical dot gain, FM 21μm.

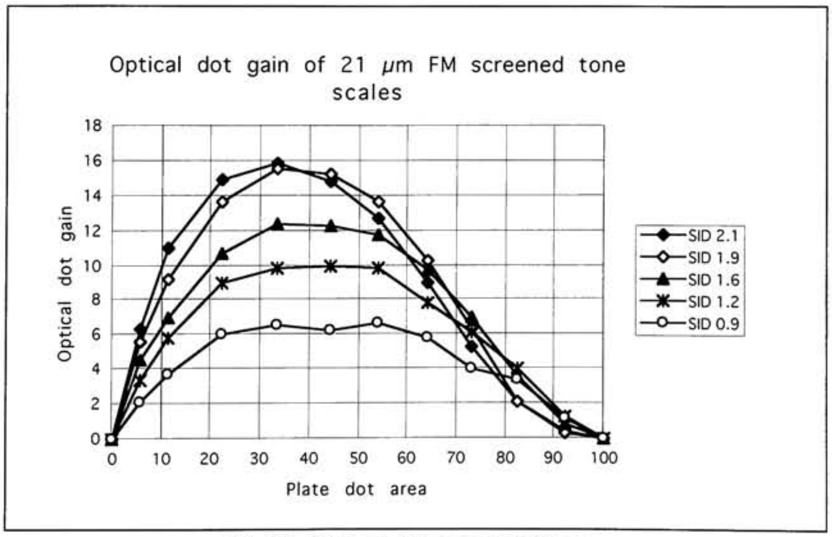


Fig.24. Optical dot gain FM, 21μm.

The optical effect is higher for the FM screened tone scale for all solid ink densities and all dot areas. At low SID (0.9) the difference in optical dot gain between the FM and AM tone scales is 1–2 % at the midtone dot area, at SID 1.6 the difference in optical dot gain is 2–3% at the midtone dot area. The difference in optical dot gain between the AM and FM tone scales when the solid ink density is increasing is small. At dot area 0.44, and SID 1.2–1.6, the optical dot gain of the FM screened tint increases 2.3% (from 10.0%–12.3%) and the optical dot gain of the AM screened tint increases 2.4% (from 7.9%–10.3%).

The n factor in the Yule-Nielsen equation corrects for the optical effect, the amount of light that is scattered and spread in the substrate. The value of n was estimated by regression analysis for the AM and FM tone scales at different SIDs. Fig.25 shows how the value of n changes with increasing solid ink density.

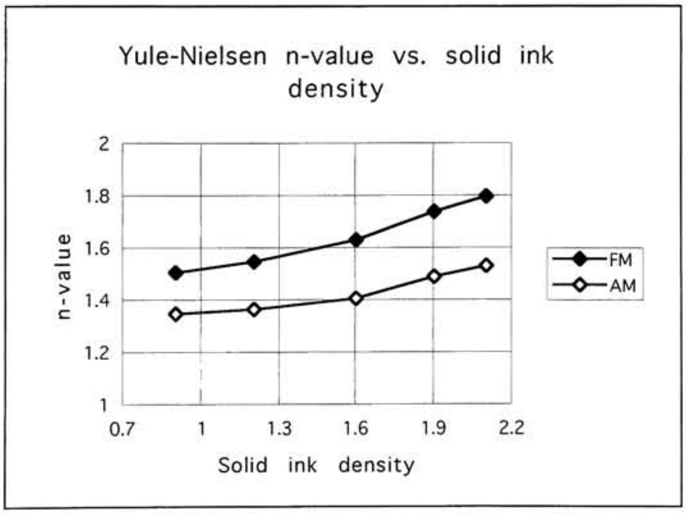


Fig.25 Estimated Yule-Nielsen n-value for AM and FM tone scales, printed at SID 0.9, 1.2, 1.6, 1.9, 2.1.

Relationship between total, mechanical and optical dot gain of FM and AM screens

Figures 26–29 show the relationship between total, mechanical and optical dot gain of the AM and FM screened tone scales for plate dot areas 23%, 44%, 64% and 83%. As seen in Fig.27–28, with increasing SID the mechanical dot gain curves of the AM and FM screened tone scales cross each others paths. The mechanical dot gain of the

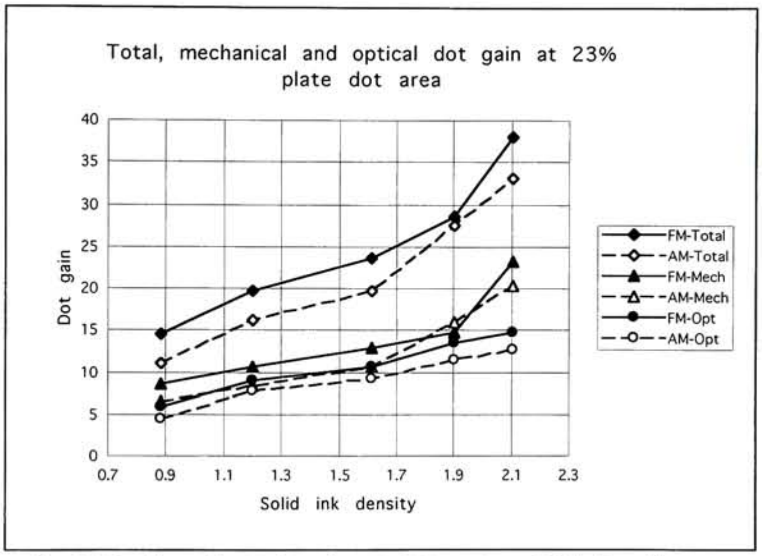


Fig.26 Total, mechanical and optical dot gain at 23% plate dot area.

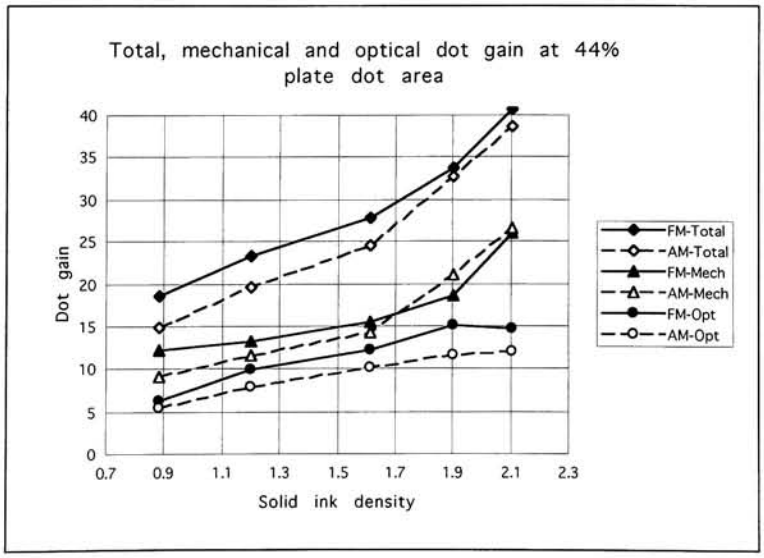


Fig.27 Total, mechanical and optical dot gain at 44% plate dot area.

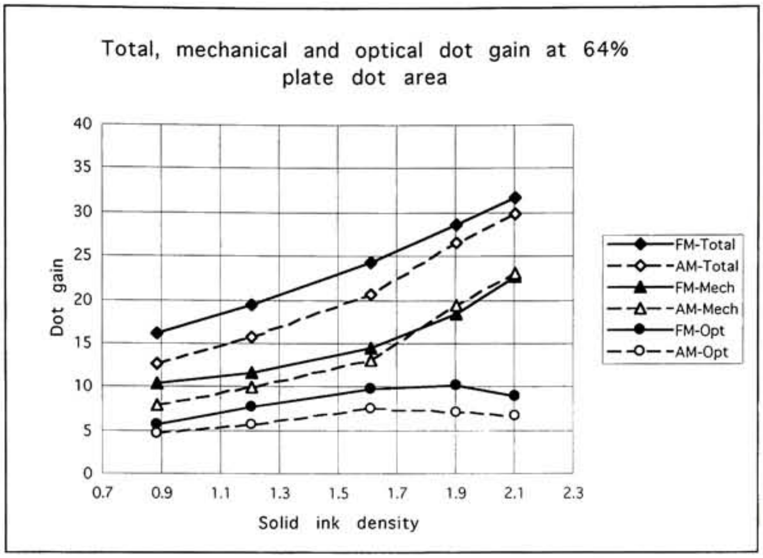


Fig.28 Total, mechanical and optical dot gain at 64% plate dot area.

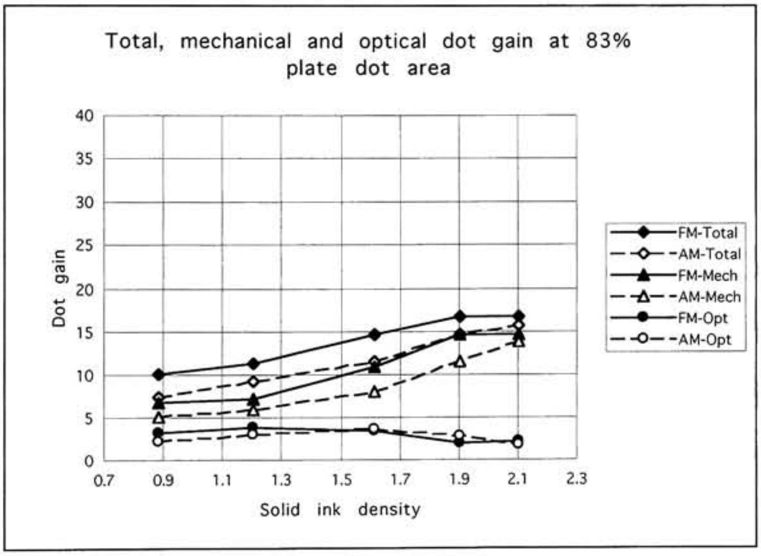


Fig.29 Total, mechanical and optical dot gain at 84% plate dot area.

AM tone scale becomes higher than the mechanical dot gain of the FM tone scale at around SID 1.7, for plate dot areas 0.44–0.64. Fig. A.7–A.16 in appendix A show the total, mechanical and optical dot gain for additional plate dot areas.

Chapter Seven

Conclusions

Hypothesis 1

FM screened tone scales have more total dot gain than AM screened tone scales, for all dot areas at low SID (0.9). Therefore hypothesis 1 will be accepted, FM tone scales have higher density than AM tone scales when printed at a low solid ink density and measured in reflection mode.

The assumption for hypothesis 1 stated that there would be no mechanical dot gain when printing at low solid ink density. It also stated that the difference in reflection density of the AM and FM tone scales is mainly due to higher optical dot gain of the FM tone scale. However, the FM tone scale had 2–3% more mechanical dot gain than the AM tone scale at the midtone dot areas. It was also found that the difference in optical dot gain of AM and FM tone scales is not as large as assumed. Therefore, the reason for accepting Hypothesis 1 is the higher amount of mechanical dot gain of the FM tone scales, in addition to the higher amount of optical dot gain.

Hypothesis 2

The transmission dot area measurements from the AM and FM tone scales at low SID (0.9) show a difference in physical dot area of the two screens. FM screens have more mechanical dot gain than AM screens measured at all dot areas. Therefore hypothesis 2 will be rejected, there is a difference in mechanical dot gain for FM and AM screens at low SID.

Mechanical dot gain is calculated relative to the measured dot area on the plate. The plate was carefully made so that there were no difference between AM and FM tints. The first two or three sheets printed from the plate actually printed with no density difference in transmission mode between the two screens. But the following prints showed more density for the FM screen than for the AM screen. This effect could be explained if the dot seen on the plate is smaller than the ink receptive dot. This could partially explain why FM screens had more mechanical dot gain than expected.

Hypothesis 3

The reflection density measurements show that the FM tone scale has more total dot gain than the AM tone scale for all SIDs. However, the AM tone scale increased more in total dot gain than the FM tone scale. At higher SID the midtone dot area of the AM tone scale is within the tolerance of ± 3%. Hypothesis 3 is therefore accepted for SID 1.9 and SID 2.1, the AM and FM tone scale have the same Murray-Davies dot area. Hypothesis 3 is rejected for solid ink densities lower than 1.9, where the AM and FM tone scales do not have the same Murray-Davies dot area.

The assumption for hypothesis 3 stated that the AM tone scale would have more mechanical dot gain and the FM tone scale would have more optical dot gain at high SID. As previously mentioned, FM screens have more mechanical dot gain than assumed. The higher amount of mechanical as well as the higher amount of optical dot gain contributes to the higher total dot gain of the FM tone scale.

Hypothesis 4

Mechanical dot gain is higher for the FM tone scale at SID 1.2–1.6, however when inking is increasing, mechanical dot gain of the AM tints increase more than mechanical dot gain of the FM tints. At higher SIDs (1.9–2.1), mechanical dot gain of the AM tone scale is higher than mechanical dot gain of the FM tone scale (for dot areas 0.44, 0.54, 0.64). Hypothesis 4 is therefore accepted for SID 1.9–2.1, AM screens have more mechanical dot gain than FM screens when printed at high solid ink densities. Hypothesis 4 is rejected for SID 1.2–1.6.

In the introduction section to this study there are two UGRA wedges printed with normal and high inking, (Fig.5–6, page 3). They show a large increase in density of the solid and of the AM 150 lpi halftone tints while only a small increase in density of the continuos tone tint. This insensitivity to changes in inking levels of fine grains can also be observed in continuos tone lithography. In contrast, when looking at the data in this study the dot gain differences between the AM and FM tone scales are relatively small. However, the basic stability effect can be observed, FM screens tend to be more stable than AM screens. The following could be reasons for the smaller dot gain differences; 1) The FM dot size may not be small enough, 2) Maybe printing on Kimdura is different than printing on paper in this aspect, 3) Maybe the effect of smaller dots carrying less ink depends on special printing conditions (ink-water balance, press speed, type of ink etc.) that are not yet well understood. The effect is real, there has been several press-runs at RIT where it has been observed. However, in other press-runs the effect did not occur.

Chapter Eight

Further Results and Findings

Dot density vs. dot size–CCD captures of tints from the Pixeldot target

Images were captured with a CCD camera from the RIT Pixeldot target. Dot sizes 21 µm–147 µm, 25 % dot area, SID: 0.9, 1.2, 1.6, 1.9, 2.1. The average reflectance values of the inked areas were obtained from the histogram in Photoshop as described in chapter 5. The reflectance values were then converted to density. In this study the term core dot density is used to describe the average ink density of the halftone dots. Fig.30 shows that the core dot density is a function of solid ink density and of dot size. When the solid ink density is increasing the core dot density is increasing as well and the core dot density of a small dot increases less than the core dot density of a larger dot. As seen in Fig.31, when the dots are 85µm and larger the

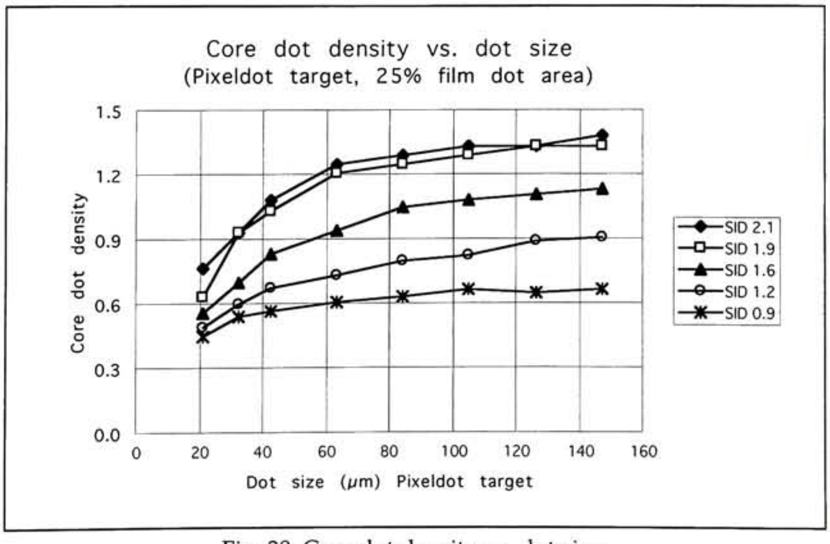


Fig. 30 Core dot density vs. dot size.

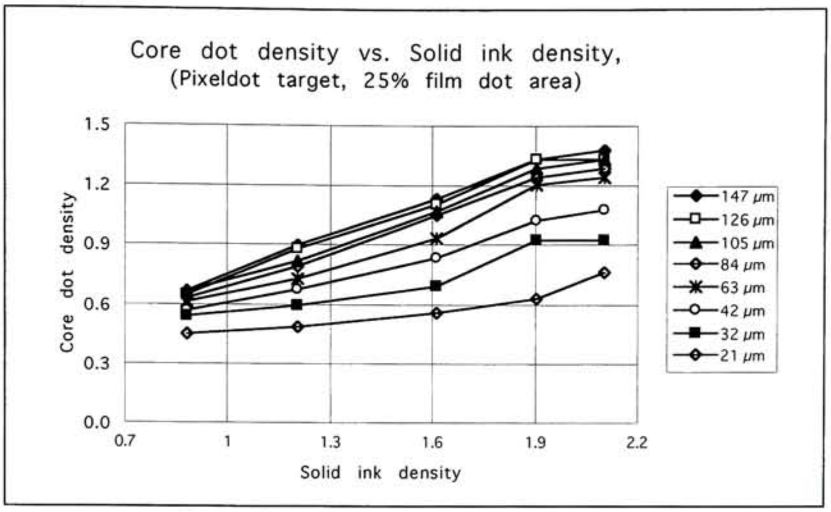


Fig.31 Core dot density vs. solid ink density

increase in core dot density, the slope of the curve, is fairly constant when inking levels increase

Difficulties occurred when choosing the central pixel value of the ink reflectance for the 2 x 2 (21 µm) dot due to the less distinct peak of the ink distribution. It is considerably easier to determine the pixel value for the 3 x 3 (32 µm) dot.

Note that the core dot density was measured with a CCD camera while the solid ink densities of the sheets in Fig.30–31 are measured with a reflection densitometer. The core dot densities of the large half tone dots are substantially lower than the measured solid ink densities. The difference could be due to the fact that the dots actually carry less ink but part of the difference is probably due to flare which is not corrected for in the data. Flare will cause the core dot densities calculated from the CCD captured half tone tints to be lower than they should be due to light reflecting from the substrate areas of the halftone tints. The difference due to calibration can not be that large because the densities measured on the solids with a densitometer and the densities measured with the CCD camera are quite close. See table B.2 in Appendix B, for the CCD solid ink densities.

CCD captures of AM and FM tone scales–dot density vs. dot area

Dots at the low dot areas are small freestanding dots, at higher tonal areas the dots start to overlap and eventually they become a solid. The solid is very sensitive to changes in inking levels, that is why it is expect of the higher dot areas to be more affected by changes in SID than the lower dot areas. Images were captured with a CCD camera from the tints of the AM and FM screened tone scales at SID 1.2, 1.6, 1.9. A measure of the average reflectance of the inked areas were obtained from the histogram in Photoshop as described in chapter five.

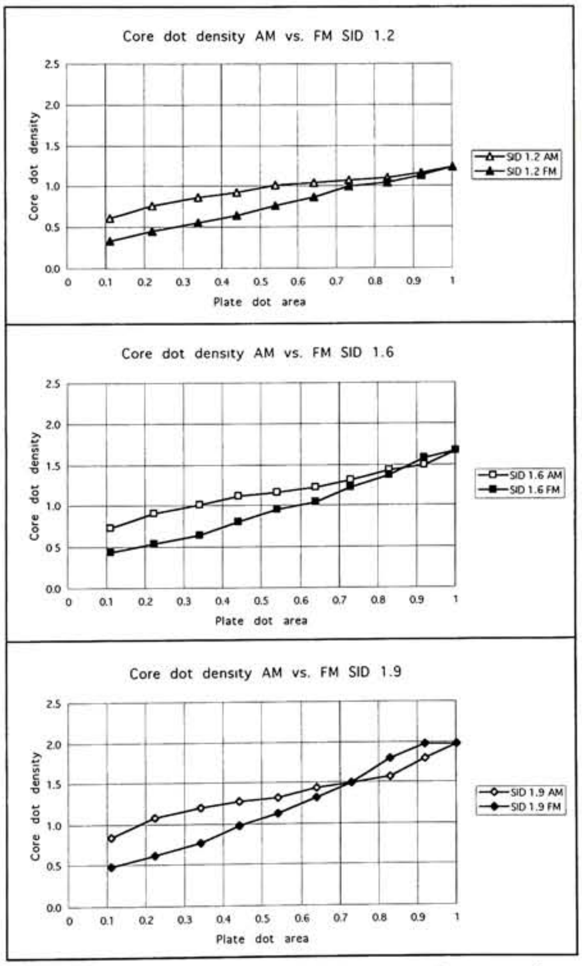


Fig.32 Comparison of core dot density of AM and FM screened tone scales at SID 1.2, 1.6 and 1.9.

Fig. 32 shows the difference in core dot density for AM and FM tone scales printed at SID 1.2, 1.6 and 1.9. The average core dot density is a function of dot area and the average core dot density of the FM tints throughout the tone scale are lower than the average core dot density of the AM tint, except for SID 1.9 where the curves of the AM and FM tone scale cross at around plate dot area 0.7.

Fig. 33–34 show the increase in core dot density of the tints in the AM tone scale and of the tints in the FM tone scale printed at SID 1.2, 1.6 and 1.9.

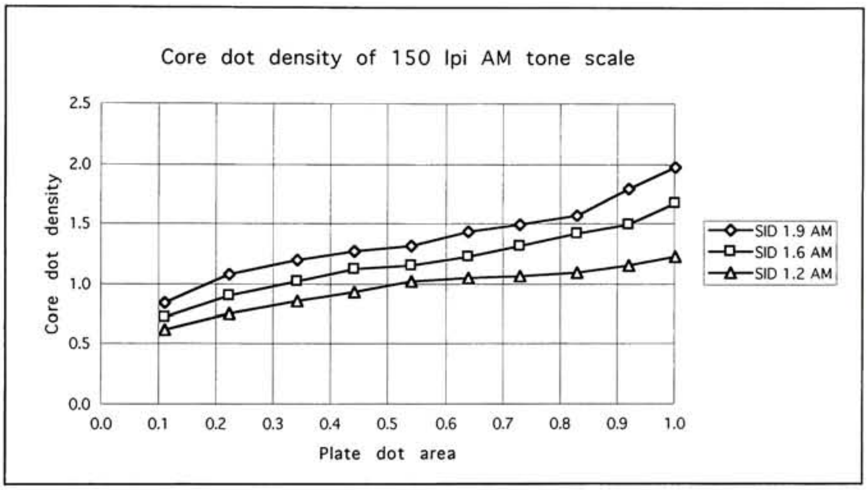


Fig.33 Core dot density AM screened tone scales at SID 1.2, 1.6 and 1.9.

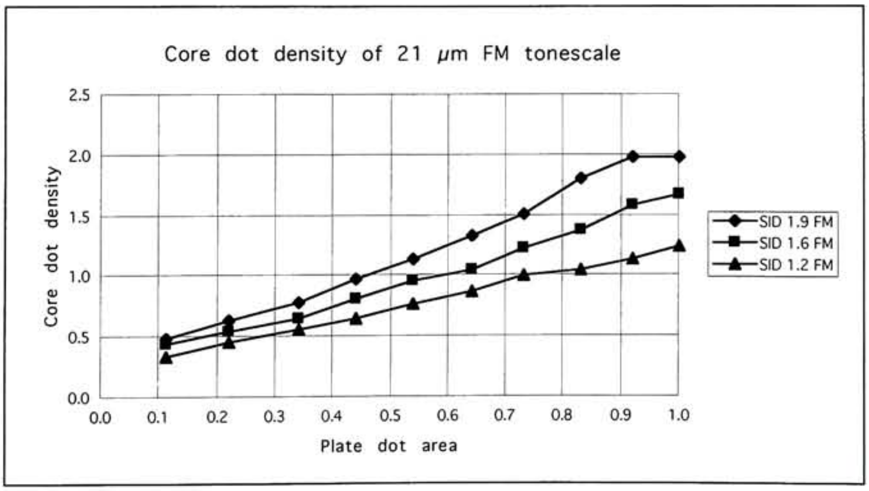


Fig.34 Core dot density of FM screened tone scales at SID 1.2, 1.6 and 1.9.

Chapter Nine

Summary and Recommendations for further study

Summary

It was found in this study that FM screens tend to be more stable on press than AM screens. FM screens are slightly more stable when printed at normal solid ink densities and the stability increases when the tone scales are printed at high SIDs.

Mechanical dot gain at low and normal SIDs is higher for FM screened tone scales, probably due to the larger border zone length of the FM screened halftone dots. However, the mechanical dot gain of the AM screened tone scale increased more than the mechanical dot gain of the FM tone scale, and at high SIDs (1.9, 2.1) the AM tone scales have more mechanical dot gain in the midtones than the FM tone scales. When looking at Fig.25, page 34 the curves of the AM and FM screen cross, but the differences may not be significant due to the printing conditions. Consequently, FM images can be printed at higher SIDs without plugging or filling in to the same degree as an AM image. The importance of this is limited due to the fact that these SIDs are extremely high and out of tolerance for a normal print run.

One of the questions of this study was if the stability of the FM screens was primarily due to a higher amount of optical dot gain. The study showed that FM screens have more optical dot gain than AM screens. It also showed, contrary to the expectation, that when the solid ink density increased the optical dot gain increased as well. The higher total dot gain of FM screens is a combination of higher optical and mechanical dot gain. The stability of the FM screens could be explained by the higher optical dot gain and the lower increase in mechanical dot gain. A possible explanation for the lower increase in mechanical dot gain could be the lower core dot density of the FM halftone dots.

The core dot density is lower for dots of sizes between 21–42 µm. The increase in core dot density is higher for dots of the size of 85µm and larger at increasing SID. The results indicate that a smaller sized dot is more stable than a larger dot and the effect of stability is gone when the dots reach the size of 85 µm. (Film dot size, the printed dot size is considerably larger). Note that the effect of flare is not accounted for, it is not possible in this study to distinguish between core dot density and flare.

A spot size of 21 µm for coated papers produces the lowest increase in core dot density and the 10.5 µm dot could not be transferred properly. The minimum FM spot size for these printing conditions would therefore be 21µm.

The average reflectance value of the ink and the average reflectance value of the substrate are not constant throughout the tone scale. Therefore, the failure of the original Murray-Davies equation is due in part to the fact that the average density of the ink and the average density of the paper change as functions of dot area.

Recommendation for further study

In this study it can not be distinguished between the amount of ink on a small dot (core dot density) and the amount of flare. An optical system with less flare could be used to take density measurements of half tone dots.

In this study an attempt was made to measure actual ink film thickness with an atomic force microscope. The atomic force microscope has a sufficient resolution for measuring ink film thickness (which is normally 1μm). The attempt was not successful due to the roughness of the substrate used in this study. If the Pixeldot target would be printed on a smoother substrate, maybe opal glass or plexiglass, it could be possible to obtain physical measurements of ink film thickness in relation to dot size.

Appendices

Appendix A

Reflection density measurements, Transmission dot area measurements, Calculations of total, mechanical and optical dot gain.

Table A.1 Reflection density measurements and total dot gain calculations of AM tonescale, SID 0.9–1.6.

% Plate dot area

AM	Dpaper	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92	100
SID 0.88	0.057	0.097	0.135	0.206	0.284	0.364	0.445	0.527	0.610	0.702	0.806	0.880
(Sheet: 3.B4)	0.056	0.097	0.135	0.203	0.283	0.362	0.448	0.523	0.609	0.698	0.813	0.887
Density average	0.057	0.097	0.135	0.205	0.284	0.363	0.447	0.525	0.610	0.700	0.810	0.884
Density-paper	0.000	0.041	0.079	0.148	0.227	0.307	0.390	0.469	0.553	0.644	0.753	0.827
M-D dot area		10.5	19.4	33.9	47.8	59.5	69.6	77.5	84.6	90.8	96.7	100.0
Total dot gain		5.0	7.7	11.2	13.9	14.9	14.8	12.7	10.9	7.4	4.7	0.0

AM	Dpaper	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92	100
SID 1.20	0.057	0.110	0.159	0.251	0.344	0.453	0.554	0.658	0.783	0.913	1.078	1.203
(Sheet:4.B4.5)	0.057	0.111	0.160	0.254	0.345	0.449	0.561	0.656	0.777	0.918	1.088	1.209
Density average	0.057	0.111	0.160	0.253	0.345	0.451	0.558	0.657	0.780	0.916	1.083	1.206
Density-paper	0.000	0.054	0.103	0.196	0.288	0.394	0.501	0.600	0.723	0.859	1.026	1.149
M-D dot area		12.5	22.6	39.0	52.1	64.2	73.6	80.6	87.3	92.7	97.5	100.0
Total dot gain		7.0	10.9	16.3	18.2	19.6	18.8	15.8	13.6	9.3	5.5	0.0

AM	Dpaper	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92	100
SID 1.37	0.056	0.118	0.171	0.269	0.378	0.492	0.634	0.751	0.880	1.054	1.256	1.376
(Sheet:1.B.5)	0.056	0.120	0.170	0.269	0.378	0.494	0.625	0.745	0.893	1.058	1.218	1.362
Density average	0.056	0.119	0.171	0.269	0.378	0.493	0.630	0.748	0.887	1.056	1.237	1.369
Density-paper	0.000	0.063	0.115	0.213	0.322	0.437	0.574	0.692	0.831	1.000	1.181	1.313
M-D dot area		14.2	24.4	40.7	55.0	66.7	77.0	83.8	89.6	94.6	98.2	100.0
Total dot gain		8.7	12.7	18.0	21.1	22.1	22.2	19.0	15.9	11.2	6.2	0.0

AM	Dpaper	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92	100
SID 1.61	0.057	0.123	0.181	0.290	0.409	0.543	0.682	0.830	0.982	1.186	1.405	1.627
(Sheet:1.1.5-1.6)	0.058	0.124	0.183	0.289	0.408	0.541	0.684	0.829	0.998	1.170	1.413	1.589
Density average	0.058	0.124	0.182	0.290	0.409	0.542	0.683	0.830	0.990	1.178	1.409	1.608
Density-paper	0.000	0.066	0.125	0.232	0.351	0.485	0.626	0.772	0.933	1.121	1.352	1.551
M-D dot area		14.5	25.6	42.6	57.0	69.2	78.5	85.5	90.9	95.1	98.3	100.0
Total dot gain		9.0	13.9	19.9	23.1	24.6	23.7	20.7	17.2	11.7	6.3	0.0

Table A.1 Reflection density measurements and total dot gain calculations of AM tone scales, SID 0.9–1.6, X-Rite 938 Spectrodensitometer, black backing.

Table A.1 (continued) Reflection density measurements and total dot gain calculations of AM tonescale, SID 1.9–2.1.

		% Plate dot area									
AM	Dpaper	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92	100
SID 1.90	0.057	0.139	0.215	0.351	0.506	0.686	0.866	1.064	1.308	1.527	1.774	1.910
(Sheet:1.8-1.9(2))	0.057	0.140	0.211	0.358	0.503	0.677	0.871	1.058	1.284	1.544	1.752	1.897
Density average	0.057	0.140	0.213	0.355	0.505	0.682	0.869	1.061	1.296	1.536	1.763	1.904
Density-paper	0.000	0.083	0.156	0.298	0.448	0.625	0.812	1.004	1.239	1.479	1.706	1.847
M-D dot area		17.6	30.6	50.3	65.2	77.4	85.8	91.4	95.6	98.1	99.4	100.0
Total dot gain		12.1	18.9	27.6	31.3	32.8	31.0	26.6	21.9	14.7	7.4	0.0

AM	Dpaper	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92	100
SID 1.92	0.056	0.147	0.231	0.387	0.558	0.752	0.955	1.160	1.406	1.644	1.804	1.929
(Sheet:1.B.5.5)	0.056	0.147	0.232	0.385	0.557	0.757	0.951	1.158	1.398	1.634	1.804	1.914
Density average	0.056	0.147	0.232	0.386	0.558	0.755	0.953	1.159	1.402	1.639	1.804	1.922
Density-paper	0.000	0.091	0.176	0.330	0.502	0.699	0.897	1.103	1.346	1.583	1.748	1.866
M-D dot area		19.2	33.7	54.0	69.4	81.1	88.5	93.4	96.8	98.7	99.6	100.0
Total dot gain		13.7	22.0	31.3	35.5	36.5	33.7	28.6	23.1	15.3	7.6	0.0

AM	Dpaper	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92	100
SID 2.10	0.056	0.150	0.235	0.406	0.598	0.816	1.046	1.276	1.549	1.823	2.004	2.085
(Sheet:1.B.6)	0.056	0.146	0.236	0.406	0.592	0.817	1.035	1.272	1.559	1.794	1.967	2.100
Density average	0.056	0.148	0.236	0.406	0.595	0.817	1.041	1.274	1.554	1.809	1.986	2.093
Density-paper	0.000	0.092	0.180	0.350	0.539	0.761	0.985	1.218	1.498	1.753	1.930	2.037
M-D dot area		19.3	34.2	55.8	71.8	83.4	90.5	94.8	97.7	99.1	99.7	100.0
Total dot gain		13.8	22.5	33.1	37.9	38.8	35.7	30.0	24.0	15.7	7.7	0.0

Table A.1(continued) Reflection density measurements and total dot gain calculations of AM tone scales, SID 1.9–2.1, X-Rite 938 Spectrodensitometer, black backing.

Figure A.1 Total dot gain of AM screened tone scale, 150 lpi Agfa Balanced Screening (square dot).

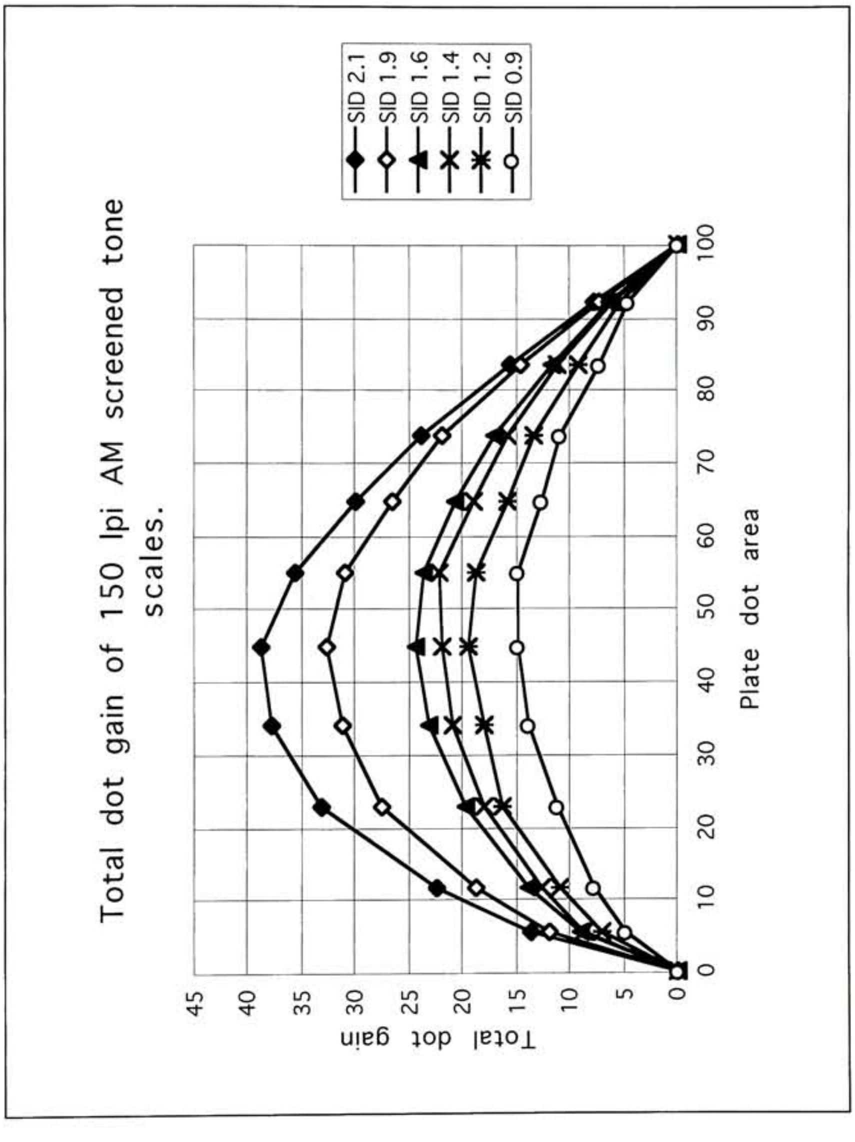


Figure A.1 Total dot gain of AM screened tone scale, 150 lpi Agfa Balanced Screening.

Table A.2 Reflection density measurements and total dot gain calculations of FM tonescale, SID 0.9–1.6.

% Plate dot area

FM	Dpaper	5.7	11.1	22.3	33.5	44.2	54.1	64	73.2	82.6	92	100
SID 0.88	0.057	0.101	0.143	0.217	0.301	0.385	0.472	0.551	0.627	0.729	0.817	0.879
(Sheet: 3.B4)	0.057	0.101	0.141	0.223	0.303	0.389	0.480	0.554	0.647	0.729	0.823	0.871
Density average	0.057	0.101	0.142	0.220	0.302	0.387	0.476	0.553	0.637	0.729	0.820	0.875
Density-paper	0.000	0.044	0.085	0.163	0.245	0.330	0.419	0.496	0.580	0.672	0.763	0.818
M-D dot area		11.4	21.0	36.9	50.8	62.8	73.0	80.3	86.9	92.8	97.6	100.0
Total dot gain		5.7	9.9	14.6	17.3	18.6	18.9	16.3	13.7	10.2	5.6	0.0

FM	Dpaper	5.7	11.1	22.3	33.5	44.2	54.1	64	73.2	82.6	92	100
SID 1.20	0.056	0.114	0.167	0.269	0.378	0.485	0.605	0.701	0.860	0.949	1.099	1.218
(Sheet:4.B4.5)	0.056	0.115	0.170	0.273	0.370	0.486	0.593	0.708	0.820	0.958	1.091	1.196
Density average	0.056	0.115	0.169	0.271	0.374	0.486	0.599	0.705	0.840	0.954	1.095	1.207
Density-paper	0.000	0.059	0.113	0.215	0.318	0.430	0.543	0.649	0.784	0.898	1.039	1.151
M-D dot area		13.6	24.6	42.0	55.9	67.6	76.8	83.4	89.9	94.0	97.8	100.0
Total dot gain		7.9	13.5	19.7	22.4	23.4	22.7	19.4	16.7	11.4	5.8	0.0

FM	Dpaper	5.7	11.1	22.3	33.5	44.2	54.1	64	73.2	82.6	92	100
SID 1.37	0.056	0.130	0.192	0.313	0.448	0.577	0.714	0.847	0.999	1.154	1.310	1.349
(Sheet:1.B.5)	0.055	0.129	0.198	0.317	0.449	0.575	0.705	0.849	1.008	1.156	1.289	1.368
Density average	0.056	0.130	0.195	0.315	0.449	0.576	0.710	0.848	1.004	1.155	1.300	1.359
Density-paper	0.000	0.074	0.140	0.260	0.393	0.521	0.654	0.793	0.948	1.100	1.244	1.303
M-D dot area		16.5	28.9	47.3	62.7	73.5	81.9	88.3	93.4	96.9	99.2	100.0
Total dot gain		10.8	17.8	25.0	29.2	29.3	27.8	24.3	20.2	14.3	7.2	0.0

FM	Dpaper	5.7	11.1	22.3	33.5	44.2	54.1	64	73.2	82.6	92	100
SID 1.61	0.057	0.129	0.192	0.309	0.438	0.579	0.725	0.915	1.142	1.294	1.495	1.589
(Sheet:1.1.5-1.6)	0.057	0.132	0.192	0.320	0.448	0.582	0.742	0.894	1.113	1.337	1.548	1.611
Density average	0.057	0.131	0.192	0.315	0.443	0.581	0.734	0.905	1.128	1.316	1.522	1.600
Density-paper	0.000	0.074	0.135	0.258	0.386	0.524	0.677	0.848	1.071	1.259	1.465	1.543
M-D dot area		16.0	27.5	46.0	60.6	72.1	81.3	88.3	94.2	97.3	99.4	100.0
Total dot gain		10.3	16.4	23.7	27.1	27.9	27.2	24.3	21.0	14.7	7.4	0.0

Table A.2 Reflection density measurements and total dot gain calculations of FM tone scales, SID 0.9–1.6, X-Rite 938 Spectrodensitometer, black backing.

Table A.2 (continued) Reflection density measurements and total dot gain calculations of FM tonescale, SID 1.9–2.1.

	% Plate dot area										
FM	Dpaper	5.7	11.1	22.3	33.5	44.2	54.1	64	73.2	82.6	92	100
SID 1.90	0.057	0.141	0.218	0.361	0.519	0.691	0.876	1.122	1.453	1.772	1.907	1.919
(Sheet:1.8-1.9(2))	0.057	0.141	0.215	0.359	0.519	0.697	0.887	1.124	1.467	1.767	1.916	1.919
Density average	0.057	0.141	0.217	0.360	0.519	0.694	0.882	1.123	1.460	1.770	1.912	1.919
Density-paper	0.000	0.084	0.160	0.303	0.462	0.637	0.825	1.066	1.403	1.713	1.855	1.862
M-D dot area		17.8	31.2	50.9	66.4	78.0	86.2	92.7	97.4	99.4	100.0	100.0
Total dot gain		12.1	20.1	28.6	32.9	33.8	32.1	28.7	24.2	16.8	8.0	0.0

FM	Dpaper	5.7	11.1	22.3	33.5	44.2	54.1	64	73.2	82.6	92	100
SID 1.92	0.056	0.153	0.235	0.398	0.576	0.747	0.931	1.191	1.472	1.801	1.902	1.923
(Sheet:1.B.5.5)	0.056	0.150	0.236	0.402	0.570	0.742	0.940	1.182	1.505	1.795	1.907	1.942
Density average	0.056	0.152	0.236	0.400	0.573	0.745	0.936	1.187	1.489	1.798	1.905	1.933
Density-paper	0.000	0.096	0.180	0.344	0.517	0.689	0.880	1.131	1.433	1.742	1.849	1.877
M-D dot area		20.0	34.3	55.4	70.5	80.6	88.0	93.8	97.6	99.5	99.9	100.0
Total dot gain		14.3	23.2	33.1	37.0	36.4	33.9	29.8	24.4	16.9	7.9	0.0

FM	Dpaper	5.7	11.1	22.3	33.5	44.2	54.1	64	73.2	82.6	92	100
SID 2.10	0.055	0.155	0.256	0.449	0.653	0.865	1.089	1.353	1.658	1.922	2.057	2.124
(Sheet:1.B.6)	0.056	0.154	0.257	0.456	0.648	0.859	1.082	1.358	1.657	1.915	2.062	2.129
Density average	0.056	0.155	0.257	0.453	0.651	0.862	1.086	1.356	1.658	1.919	2.060	2.127
Density-paper	0.000	0.099	0.201	0.397	0.595	0.807	1.030	1.300	1.602	1.863	2.004	2.071
M-D dot area		20.6	37.4	60.4	75.2	85.1	91.4	95.8	98.3	99.5	99.9	100.0
Total dot gain		14.9	26.3	38.1	41.7	40.9	37.3	31.8	25.1	16.9	7.9	0.0

Table A.2(continued) Reflection density measurements and total dot gain calculations of FM tone scales, SID 1.9–2.1, X-Rite 938 Spectrodensitometer, black backing.

Figure A.2 Total dot gain of FM screened tone scale, 21 µm Agfa Cristal raster.

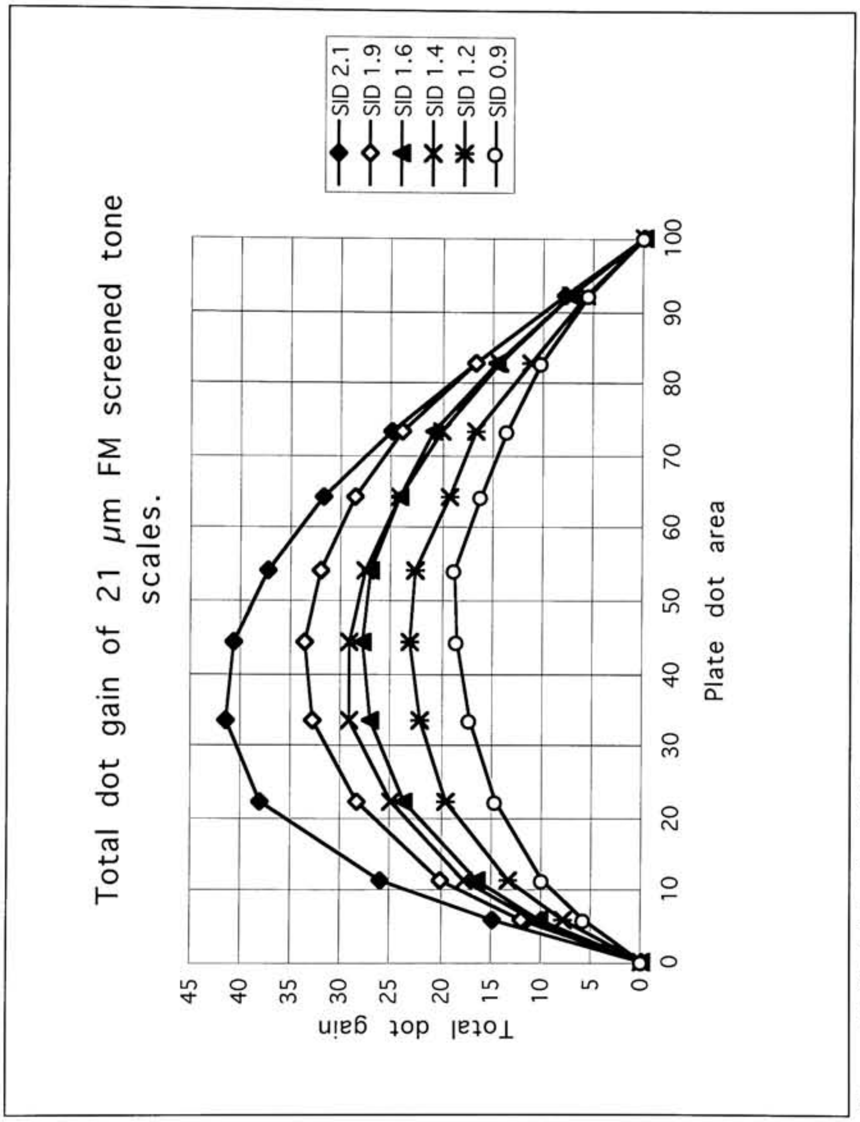


Figure A.2 Total dot gain of FM screened tone scale, 21 µm Agfa Cristal Raster.

Table A.3 Transmission dot area measurements and mechanical dot gain calculations of AM tonescale, SID 0.9–1.6.

% Plate dot area

AM	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92.0	100.0
SID 0.88	5.7	11.0	20.2	29.1	37.1	44.2	50.0	56.1	60.9	65.3	68.8
(Sheet: 3.B4)	5.2	10.5	19.5	28.0	35.8	42.6	48.4	53.8	58.9	63.2	66.3
Transm. dot area average.	5.5	10.8	19.9	28.6	36.5	43.4	49.2	55.0	59.9	64.3	67.6
Transm. dot area norm.	8.1	15.9	29.4	42.3	54.0	64.2	72.8	81.3	88.7	95.1	100.0
Mechanical dot gain	2.5	4.2	6.7	8.4	9.3	9.4	8.1	7.7	5.2	3.1	0.0

AM	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92.0	100.0
SID 1.20	7.2	13.2	23.5	33.5	42.4	50.1	56.0	62.5	67.3	72.0	75.5
(Sheet:4.B4.5)	6.8	12.6	23.2	33.1	42.1	49.8	56.1	62.2	67.0	72.0	74.5
Transm. dot area average.	7.0	12.9	23.4	33.3	42.3	50.0	56.1	62.4	67.2	72.0	75.0
Transm. dot area norm.	9.3	17.2	31.1	44.4	56.3	66.6	74.7	83.1	89.5	96.0	100.0
Mechanical dot gain	3.8	5.5	8.4	10.5	11.7	11.8	10.0	9.4	6.1	4.0	0.0

AM	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92.0	100.0
SID 1.37	8.4	14.7	25.1	36.4	45.3	54.1	59.5	66.2	72.3	75.5	78.7
(Sheet:1.B.5)	8.7	14.3	25.3	37.2	46.2	55.9	61.9	67.8	73.0	77.4	80.0
Transm. dot area average.	8.6	14.5	25.2	36.8	45.8	55.0	60.7	67.0	72.7	76.5	79.4
Transm. dot area norm.	10.8	18.3	31.8	46.4	57.7	69.3	76.5	84.4	91.6	96.3	100.0
Mechanical dot gain	5.2	6.6	9.1	12.5	13.0	14.5	11.7	10.7	8.1	4.4	0.0

AM	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92.0	100.0
SID 1.61	9.0	16.4	28.5	40.0	50.0	59.0	66.0	72.7	77.9	82.3	85.3
(Sheet:1.1.5-1.6)	9.1	16.6	28.5	40.2	50.5	59.3	66.8	73.0	78.1	83.0	85.3
Transm. dot area average.	9.1	16.5	28.5	40.1	50.3	59.2	66.4	72.9	78.0	82.7	85.3
Transm. dot area norm.	10.6	19.3	33.4	47.0	58.9	69.3	77.8	85.4	91.4	96.9	100.0
Mechanical dot gain	5.1	7.7	10.7	13.1	14.3	14.5	13.1	11.7	8.0	4.9	0.0

Table A.3 Transmission dot area measurements and mechanical dot gain calculations of AM tone scales, SID 0.9–1.6. Transmission dot area meter, no filters, custom built by Franz Sigg, RIT.

Table A.3 (continued) Transmission dot area measurements and mechanical dot gain calculations of AM tonescale, SID 1.9–2.1.

% Plate dot area

AM	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92.0	100.0
SID 1.90	11.2	20.1	34.1	48.2	59.9	69.4	76.9	83.4	86.8	89.9	91.3
(Sheet:1.8-1.9(2))	12.4	21.3	36.5	49.8	61.7	71.3	79.1	85.7	89.3	92.4	93.8
Transm. dot area average.	11.8	21.0	35.9	49.0	60.8	70.3	78.0	84.6	88.1	91.2	92.6
Transm. dot area norm.	12.7	22.7	38.8	52.9	65.7	76.0	84.3	91.4	95.1	98.5	100.0
Mechanical dot gain	7.2	11.0	16.1	19.1	21.1	21.1	19.5	17.7	11.7	6.5	0.0

AM	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92.0	100.0
SID 1.92	12.5	22.3	37.5	50.7	62.1	71.1	77.6	84.0	86.9	89.0	90.0
(Sheet:1.B.5.5)	12.2	22.1	37.8	50.8	62.2	71.4	78.3	84.2	87.4	89.5	90.1
Transm. dot area average.	12.4	22.2	37.7	50.8	62.2	71.3	78.0	84.1	87.2	89.3	90.1
Transm. dot area norm.	13.7	24.7	41.8	56.4	69.0	79.1	86.6	93.4	96.8	99.1	100.0
Mechanical dot gain	8.2	13.0	19.1	22.5	24.4	24.3	21.8	19.7	13.3	7.1	0.0

AM	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92.0	100.0
SID 2.10	12.5	22.8	38.9	53.0	64.9	73.8	79.8	85.3	88.5	90.0	90.9
(Sheet:1.B.6)	12.7	23.2	40.0	53.6	65.6	74.9	81.1	86.3	89.3	91.2	91.9
Transm. dot area average.	12.6	23.0	39.5	53.3	65.3	74.4	80.5	85.8	88.9	90.6	91.4
Transm. dot area norm.	13.8	25.2	43.2	58.3	71.4	81.3	88.0	93.9	97.3	99.1	100.0
Mechanical dot gain	8.3	13.5	20.5	24.4	26.7	26.5	23.2	20.2	13.8	7.2	0.0

Table A.3 Transmission dot area measurements and mechanical dot gain calculations of AM tone scales, SID 1.9–2.1. Transmission dot area meter, no filters, custom built by Franz Sigg, RIT.

Figure A.3 Mechanical dot gain of AM screened tone scale, 150 lpi Agfa Balanced Screening (square dot).

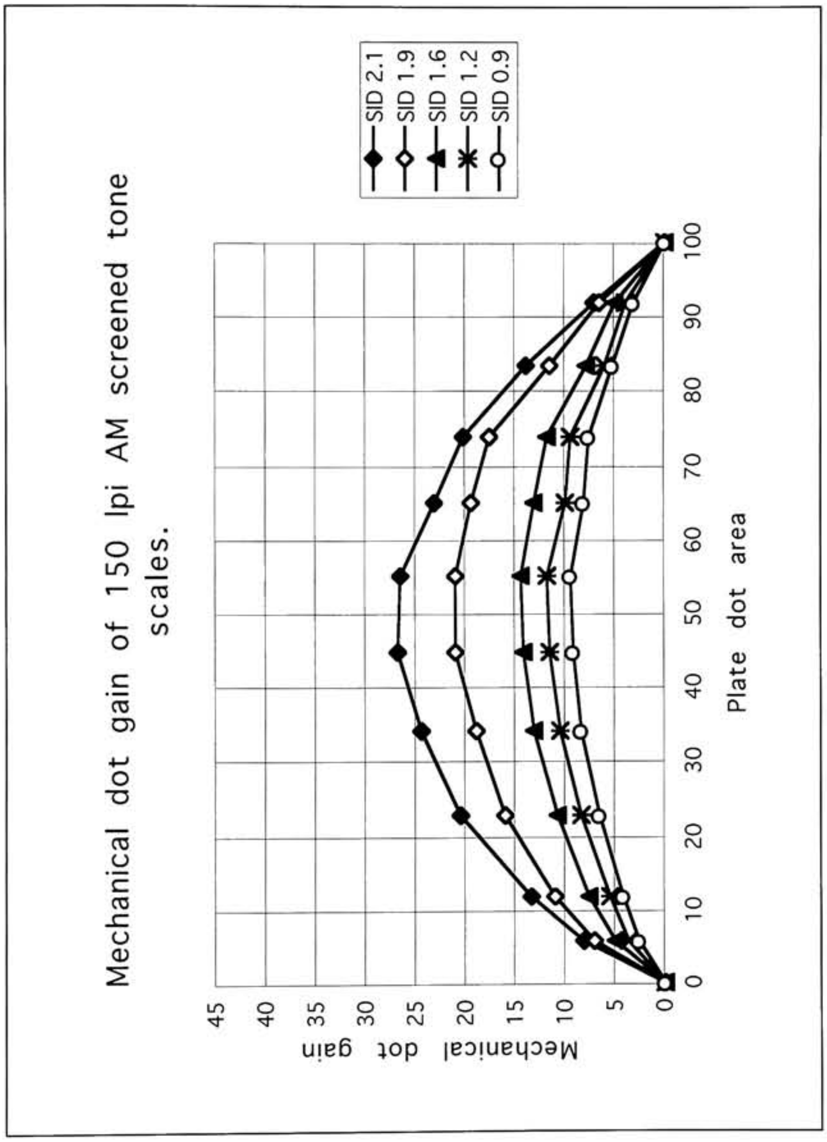


Figure A.3 Mechanical dot gain of AM screened tone scale, 150 lpi Agfa Balanced Screening.

Table A.4 Transmission dot area measurements and mechanical dot gain calculations of FM tonescale, SID 0.9–1.6.

% Plate dot area

FM	5.7	11.1	22.3	33.5	44.2	54.1	64.0	73.2	82.6	92.0	100.0
SID 0.88	6.3	11.9	21.5	30.8	39.4	45.9	51.6	57.3	61.9	66.8	69.4
(Sheet: 3.B4)	6.2	11.5	20.3	29.2	37.2	43.9	49.3	55.0	59.2	63.8	66.1
Transm. dot area average.	6.3	11.7	20.9	30.0	38.3	44.9	50.5	56.2	60.6	65.3	67.8
Transm. dot area norm.	9.2	17.3	30.8	44.3	56.5	66.3	74.5	82.9	89.4	96.4	100.0
Mechanical dot gain	3.6	6.2	8.6	10.8	12.3	12.2	10.4	9.7	6.8	4.4	0.0

FM	5.7	11.1	22.3	33.5	44.2	54.1	64.0	73.2	82.6	92.0	100.0
SID 1.20	7.7	14.0	24.6	34.9	43.2	50.1	56.5	63.1	67.4	71.9	74.7
(Sheet:4.B4.5)	7.4	13.9	24.5	33.5	42.5	49.5	56.1	61.5	66.4	71.7	74.1
Transm. dot area average.	7.6	14.0	24.6	34.2	42.9	49.8	56.3	62.3	66.9	71.8	74.4
Transm. dot area norm.	10.1	18.8	33.0	46.0	57.6	66.9	75.7	83.7	89.9	96.5	100.0
Mechanical dot gain	4.5	7.7	10.7	12.5	13.4	12.9	11.6	10.5	7.4	4.5	0.0

FM	5.7	11.1	22.3	33.5	44.2	54.1	64.0	73.2	82.6	92.0	100.0
SID 1.37	9.9	17.2	29.3	40.7	49.3	56.2	62.4	69.3	73.9	77.4	79.1
(Sheet:1.B.5)	9.3	17.0	28.7	40.3	49.0	57.3	63.1	69.2	73.9	78.2	79.4
Transm. dot area average.	9.6	17.1	29.0	40.5	49.2	56.8	62.8	69.3	73.9	77.8	79.3
Transm. dot area norm.	12.1	21.6	36.6	51.1	62.0	71.6	79.2	87.4	93.2	98.2	100.0
Mechanical dot gain	6.4	10.5	14.3	17.6	17.8	17.5	15.1	14.2	10.7	6.2	0.0

FM	5.7	11.1	22.3	33.5	44.2	54.1	64.0	73.2	82.6	92.0	100.0
SID 1.61	9.8	17.4	30.1	41.0	51.1	59.2	66.6	74.2	79.7	83.7	84.8
(Sheet:1.1.5-1.6)	9.7	17.4	29.9	40.9	50.6	58.8	66.9	74.0	79.4	83.8	85.1
Transm. dot area average.	9.8	17.4	30.0	41.0	50.9	59.0	66.8	74.1	79.6	83.8	85.0
Transm. dot area norm.	11.5	20.5	35.3	48.2	59.9	69.4	78.6	87.2	93.6	98.6	100.0
Mechanical dot gain	5.8	9.4	13.1	14.7	15.6	15.4	14.5	14.0	11.1	6.6	0.0

Table A.4 Transmission dot area measurements and mechanical dot gain calculations of FM tone scales, SID 0.9–1.6. Transmission dot area meter, no filters, custom built by Franz Sigg, RIT.

Table A.4 (continued) Transmission dot area measurements and mechanical dot gain calculations of FM tonescale, SID 1.9–2.1.

% Plate dot area											
FM	5.7	11.1	22.3	33.5	44.2	54.1	64.0	73.2	82.6	92.0	100.0
SID 1.90	10.9	19.8	33.8	46.5	57.4	66.4	75.3	83.4	89.1	91.2	91.5
(Sheet:1.8-1.9(2))	11.8	20.8	35.2	47.8	59.1	68.2	77.6	85.4	91.4	93.7	94.0
Transm. dot area average.	11.4	20.3	34.5	47.2	58.3	67.3	76.5	84.4	90.3	92.5	92.8
Transm. dot area norm.	12.2	21.9	37.2	50.8	62.8	72.6	82.4	91.0	97.3	99.7	100.0
Mechanical dot gain	6.6	10.8	14.9	17.4	18.6	18.5	18.4	17.8	14.7	7.7	0.0

FM	5.7	11.1	22.3	33.5	44.2	54.1	64.0	73.2	82.6	92.0	100.0
SID 1.92	12.6	21.8	36.9	49.2	59.4	67.5	75.7	83.5	88.2	90.2	90.7
(Sheet:1.B.5.5)	12.7	22.2	37.2	49.5	59.3	67.5	76.1	83.6	88.2	90.2	90.7
Transm. dot area average.	12.7	22.0	37.1	49.4	59.4	67.5	75.9	83.6	88.2	90.2	90.7
Transm. dot area norm.	13.9	24.3	40.8	54.4	65.4	74.4	83.7	92.1	97.2	99.4	100.0
Mechanical dot gain	8.3	13.2	18.6	20.9	21.2	20.3	19.6	18.9	14.7	7.5	0.0

FM	5.7	11.1	22.3	33.5	44.2	54.1	64.0	73.2	82.6	92.0	100.0
SID 2.10	12.9	24.0	41.6	54.2	64.4	71.9	79.2	85.0	88.8	90.8	91.2
(Sheet:1.B.6)	13.2	24.3	41.8	54.7	64.6	72.6	80.1	85.7	89.7	91.7	92.3
Transm. dot area average.	13.1	24.2	41.7	54.5	64.5	72.3	79.7	85.4	89.3	91.3	91.8
Transm. dot area norm.	14.2	26.3	45.4	59.3	70.3	78.7	86.8	93.0	97.3	99.5	100.0
Mechanical dot gain	8.6	15.3	23.2	25.9	26.1	24.7	22.8	19.8	14.7	7.5	0.0

Table A.4 (continued) Transmission dot area measurements and mechanical dot gain calculations of FM tone scales, SID 1.9–2.1. Transmission dot area meter, no filters, custom built by Franz Sigg, RIT.

Figure A.4 Mechanical dot gain of FM screened tone scale, 21 µm Agfa Cristal raster.

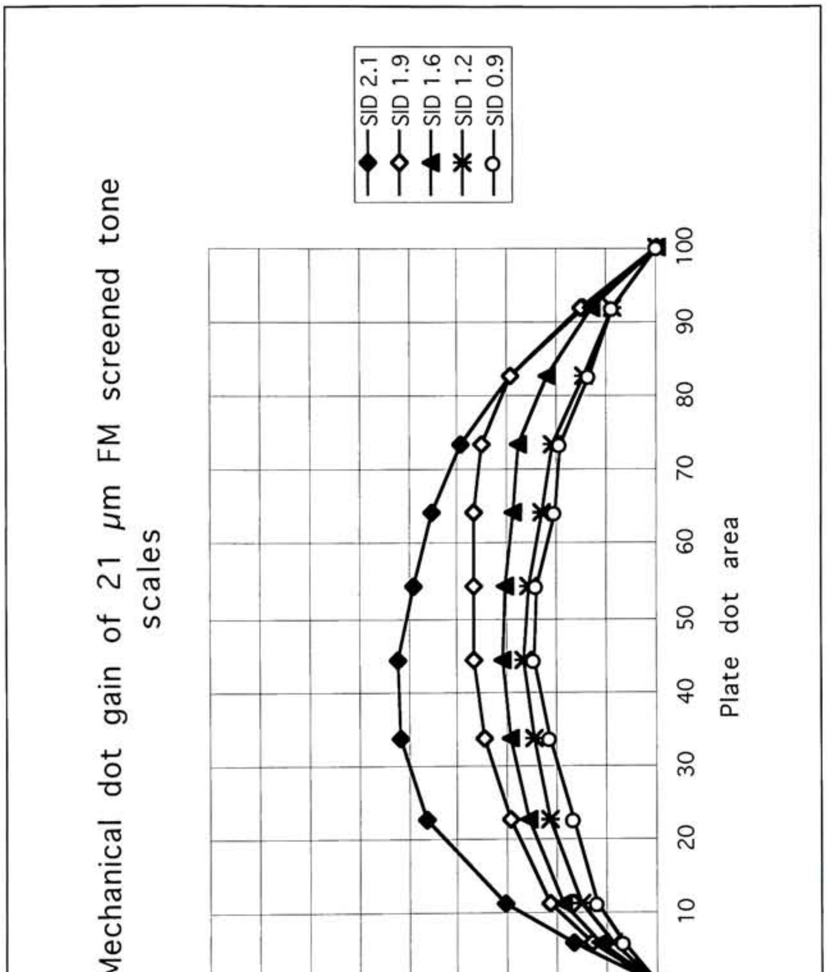


Figure A.4 Mechanical dot gain of FM screened tone scale, 21 µm Agfa Cristal Raster.

Table A.5 Calculations of optical dot gain of AM tone scale, SID 0.9–1.6.

AM SID 0.88	% Plate dot area										
(Sheet: 3.B4)	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92.0	100.0
Total dot gain	5.0	7.7	11.2	13.9	14.9	14.8	12.7	10.9	7.4	4.7	0.0
Mechanical dot gain	2.5	4.2	6.7	8.4	9.3	9.4	8.1	7.7	5.2	3.1	0.0
Optical dot gain	2.4	3.5	4.5	5.5	5.6	5.4	4.7	3.3	2.2	1.6	0.0
AM SID 1.20											
(Sheet:4.B4.5)	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92.0	100.0
Total dot gain	7.0	10.9	16.3	18.2	19.6	18.8	15.8	13.6	9.3	5.5	0.0
Mechanical dot gain	3.8	5.5	8.4	10.5	11.7	11.8	10.0	9.4	6.1	4.0	0.0
Optical dot gain	3.2	5.4	7.9	7.7	7.9	7.0	5.8	4.1	3.2	1.5	0.0
AM SID 1.37											
(Sheet:1.B.5)	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92.0	100.0
Total dot gain	8.7	12.7	18.0	21.1	22.1	22.2	19.0	15.9	11.2	6.2	0.0
Mechanical dot gain	5.2	6.6	9.1	12.5	13.0	14.5	11.7	10.7	8.1	4.4	0.0
Optical dot gain	3.4	6.1	9.0	8.6	9.1	7.7	7.2	5.1	3.1	1.8	0.0
AM SID 1.61											
(Sheet:1.1.5-1.6)	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92.0	100.0
Total dot gain	9.0	13.9	19.9	23.1	24.6	23.7	20.7	17.2	11.7	6.3	0.0
Mechanical dot gain	5.1	7.7	10.7	13.1	14.3	14.5	13.1	11.7	8.0	4.9	0.0
Optical dot gain	3.9	6.3	9.2	10.0	10.3	9.2	7.6	5.5	3.7	1.4	0.0

Table A.5 Comparisons of total, mechanical and optical dot gain of AM tone scales, SID 0.9–1.6.

Table A.5 (continued) Calculations of optical dot gain of AM tone scale, SID 1.9–2.1.

AM SID 1.90 (Sheet:1.8-1.9(2))	% Plate dot area 5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92.0	100.0
Total dot gain	12.1	18.9	27.6	31.3	32.8	31.0	26.6	21.9	14.7	7.4	0.0
Mechanical dot gain	7.2	11.0	16.1	19.1	21.1	21.1	19.5	17.7	11.7	6.5	0.0
Optical dot gain	4.8	7.9	11.5	12.3	11.7	9.8	7.1	4.2	3.0	0.9	0.0

AM SID 1.92 (Sheet:1.B.5.5)	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92.0	100.0
Total dot gain	13.7	22.0	31.3	35.5	36.5	33.7	28.6	23.1	15.3	7.6	0.0
Mechanical dot gain	8.2	13.0	19.1	22.5	24.4	24.3	21.8	19.7	13.3	7.1	0.0
Optical dot gain	5.5	9.0	12.1	13.0	12.1	9.4	6.8	3.4	2.0	0.4	0.0

AM SID 2.10 (Sheet:1.B.6)	5.5	11.7	22.7	33.9	44.6	54.8	64.8	73.7	83.4	92.0	100.0
Total dot gain	13.8	22.5	33.1	37.9	38.8	35.7	30.0	24.0	15.7	7.7	0.0
Mechanical dot gain	8.3	13.5	20.5	24.4	26.7	26.5	23.2	20.2	13.8	7.2	0.0
Optical dot gain	5.5	9.0	12.7	13.4	12.1	9.1	6.8	3.8	1.9	0.6	0.0

Table A.5 (continued) Comparisons of total, mechanical and optical dot gain of AM tone scales, SID 1.9–2.1.

Figure A.5 Optical dot gain of AM screened tone scale, 150 lpi Agfa Balanced Screening (square dot).

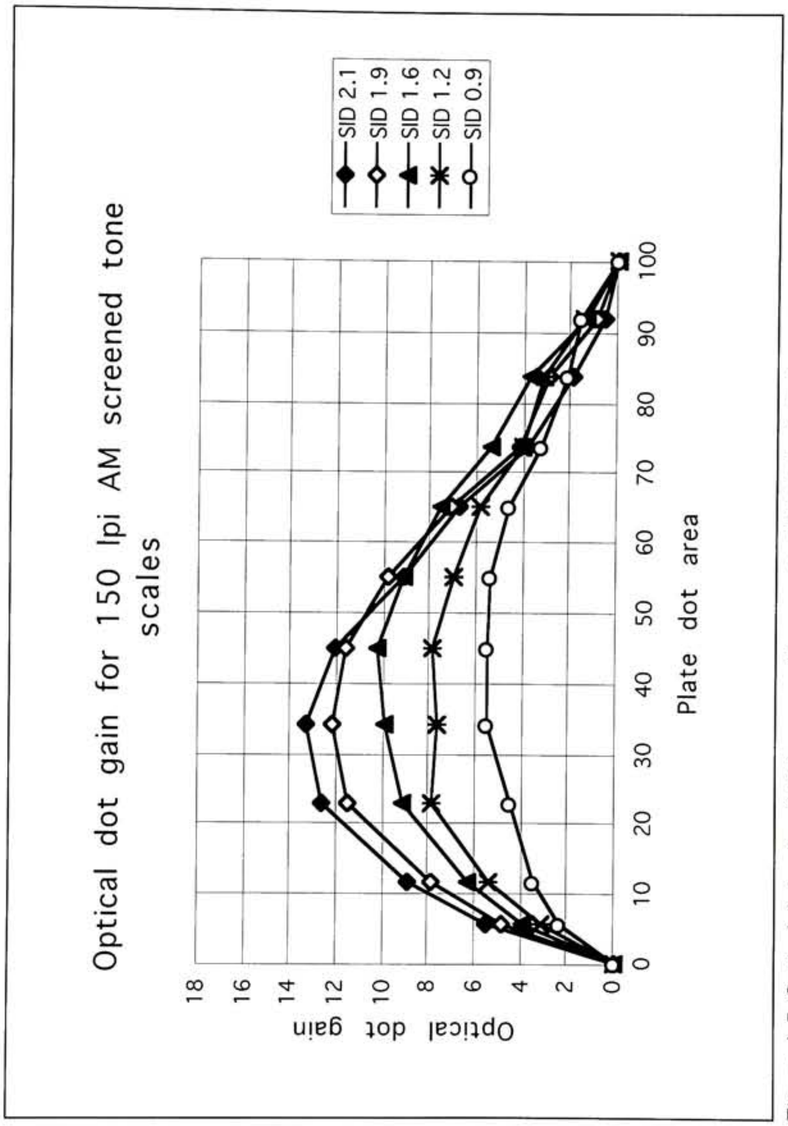


Figure A.5 Optical dot gain of AM screened tone scale, 150 lpi Agfa Balanced Screening.

Table A.6 Calculations of optical dot gain of FM tone scale, SID 0.9–1.6.

	% Plate dot area										
FM SID 0.88 (Sheet: 3.B4)	5.7	11.1	22.3	33.5	44.2	54.1	64.0	73.2	82.6	92.0	100.0
Total dot gain	5.7	9.9	14.6	17.3	18.6	18.9	16.3	13.7	10.2	5.6	0.0
Mechanical dot gain	3.6	6.2	8.6	10.8	12.3	12.2	10.4	9.7	6.8	4.4	0.0
Optical dot gain	2.1	3.7	6.0	6.5	6.3	6.7	5.8	4.0	3.4	1.2	0.0
FM SID 1.20 (Sheet:4.B4.5)	5.7	11.1	22.3	33.5	44.2	54.1	64.0	73.2	82.6	92.0	100.0
Total dot gain	7.9	13.5	19.7	22.4	23.4	22.7	19.4	16.7	11.4	5.8	0.0
Mechanical dot gain	4.5	7.7	10.7	12.5	13.4	12.9	11.6	10.5	7.4	4.5	0.0
Optical dot gain	3.4	5.8	9.0	9.9	10.0	9.8	7.8	6.2	4.0	1.2	0.0
FM SID 1.37 (Sheet:1.B.5)	5.7	11.1	22.3	33.5	44.2	54.1	64.0	73.2	82.6	92.0	100.0
Total dot gain	10.8	17.8	25.0	29.2	29.3	27.8	24.3	20.2	14.3	7.2	0.0
Mechanical dot gain	6.4	10.5	14.3	17.6	17.8	17.5	15.1	14.2	10.7	6.2	0.0
Optical dot gain	4.3	7.3	10.7	11.5	11.5	10.3	9.1	6.0	3.6	1.0	0.0
FM SID 1.61 (Sheet:1.1.5-1.6)	5.7	11.1	22.3	33.5	44.2	54.1	64.0	73.2	82.6	92.0	100.0
Total dot gain	10.3	16.4	23.7	27.1	27.9	27.2	24.3	21.0	14.7	7.4	0.0
Mechanical dot gain	5.8	9.4	13.1	14.7	15.6	15.4	14.5	14.0	11.1	6.6	0.0
Optical dot gain	4.5	7.0	10.7	12.4	12.3	11.8	9.8	7.0	3.6	0.8	0.0

Table A.6 Comparisons of total, mechanical and optical dot gain of FM tone scales, SID 0.9–1.6.

Table A.6 (continued) Calculations of optical dot gain of FM tone scale, SID 1.9–2.1.

FM SID 1.90	% Plate dot area										
(Sheet:1.8-1.9(2))	5.7	11.1	22.3	33.5	44.2	54.1	64.0	73.2	82.6	92.0	100.0
Total dot gain	12.1	20.1	28.6	32.9	33.8	32.1	28.7	24.2	16.8	8.0	0.0
Mechanical dot gain	6.6	10.8	14.9	17.4	18.6	18.5	18.4	17.8	14.7	7.7	0.0
Optical dot gain	5.6	9.2	13.7	15.5	15.2	13.6	10.3	6.4	2.1	0.3	0.0
FM SID 1.92											
(Sheet:1.B.5.5)	5.7	11.1	22:3	33.5	44.2	54.1	64.0	73.2	82.6	92.0	100.0
Total dot gain	14.3	23.2	33.1	37.0	36.4	33.9	29.8	24.4	16.9	7.9	0.0
Mechanical dot gain	8.3	13.2	18.6	20.9	21.2	20.3	19.6	18.9	14.7	7.5	0.0
Optical dot gain	6.0	10.0	14.5	16.1	15.2	13.5	10.2	5.5	2.2	0.4	0.0
FM SID 2.10											
(Sheet:1.B.6)	5.7	11.1	22.3	33.5	44.2	54.1	64.0	73.2	82.6	92.0	100.0
Total dot gain	14.9	26.3	38.1	41.7	40.9	37.3	31.8	25.1	16.9	7.9	0.0
Mechanical dot gain	8.6	15.3	23.2	25.9	26.1	24.7	22.8	19.8	14.7	7.5	0.0
Optical dot gain	6.3	11.0	14.9	15.9	14.8	12.7	9.0	5.3	2.2	0.4	0.0

Table A.6 (continued) Comparisons of total, mechanical and optical dot gain of FM tone scales, SID 1.9–2.1.

Figure A.6 Optical dot gain of FM screened tone scale, 21µm Agfa Cristal raster.

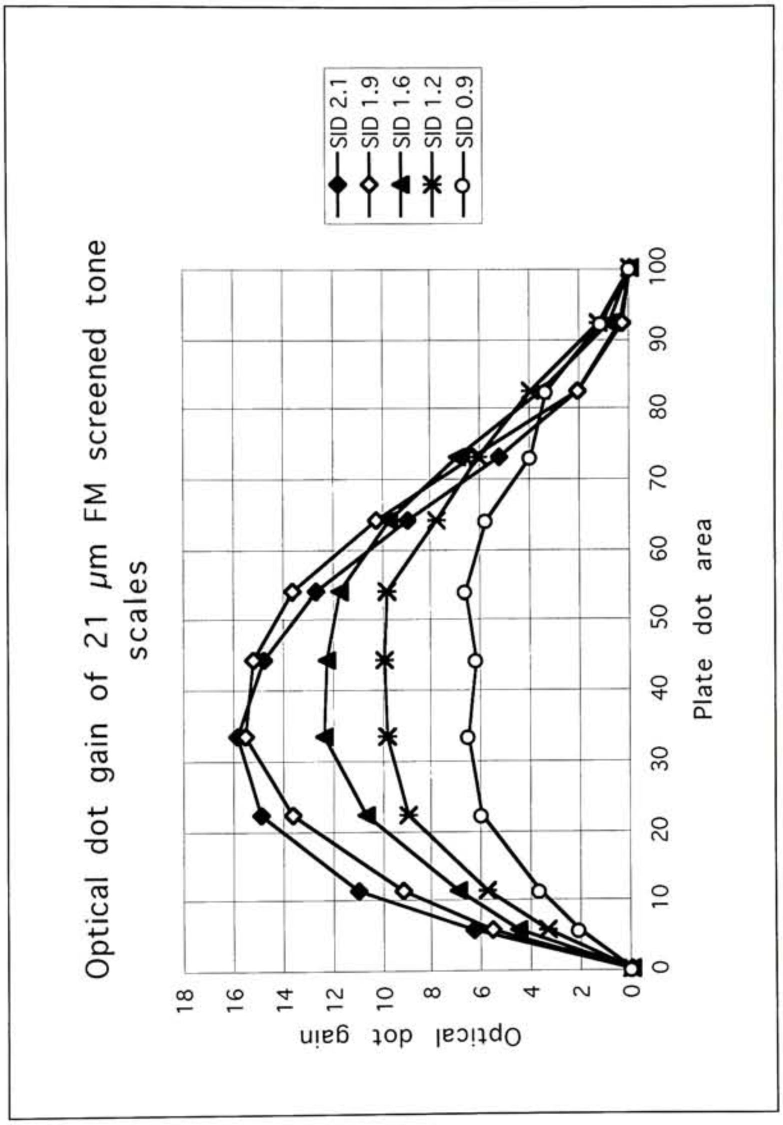


Figure A.6 Optical dot gain of FM screened tone scale, 21 µm Agfa Cristal Raster.

Figure A.7 Comparison of total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 6%.

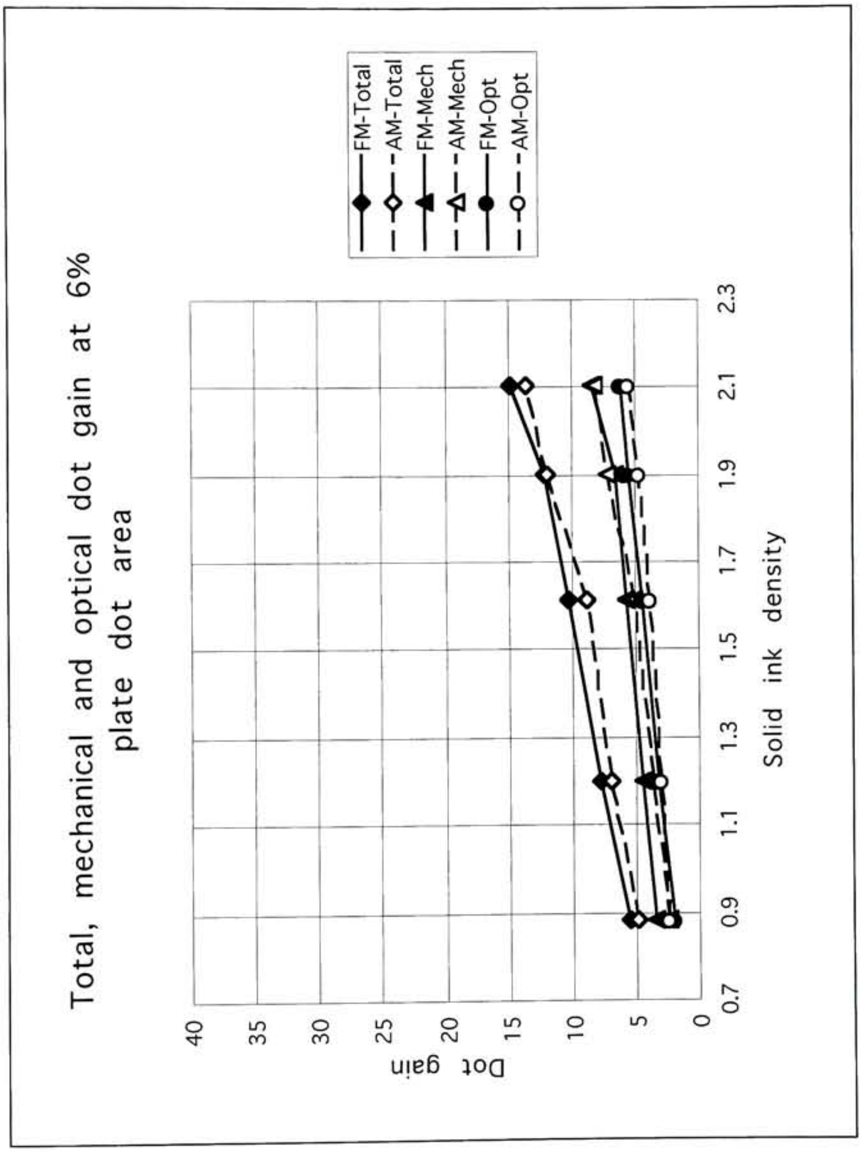


Figure A.7 Comparison of Total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 6%.

Figure A.8 Comparison of total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 11%.

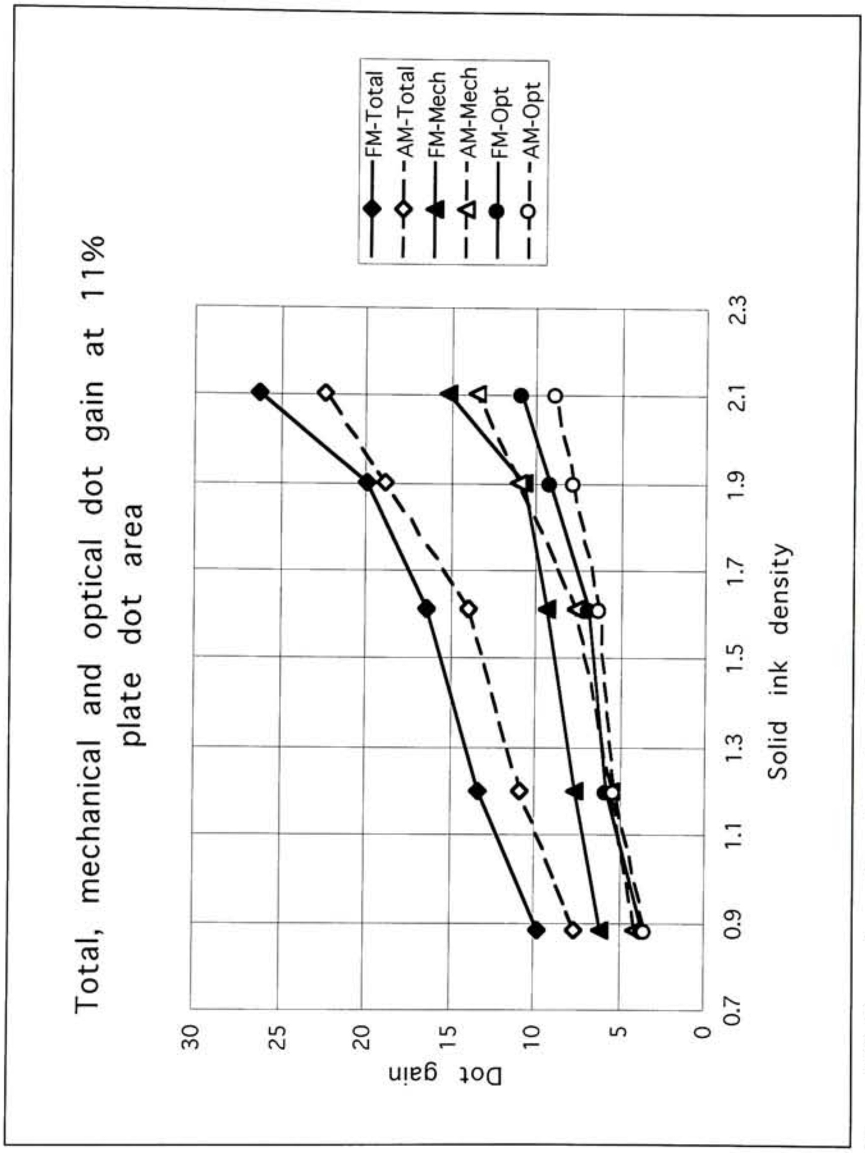


Figure A.8 Comparison of total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 11%.

Figure A.9 Comparison of total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 23%.

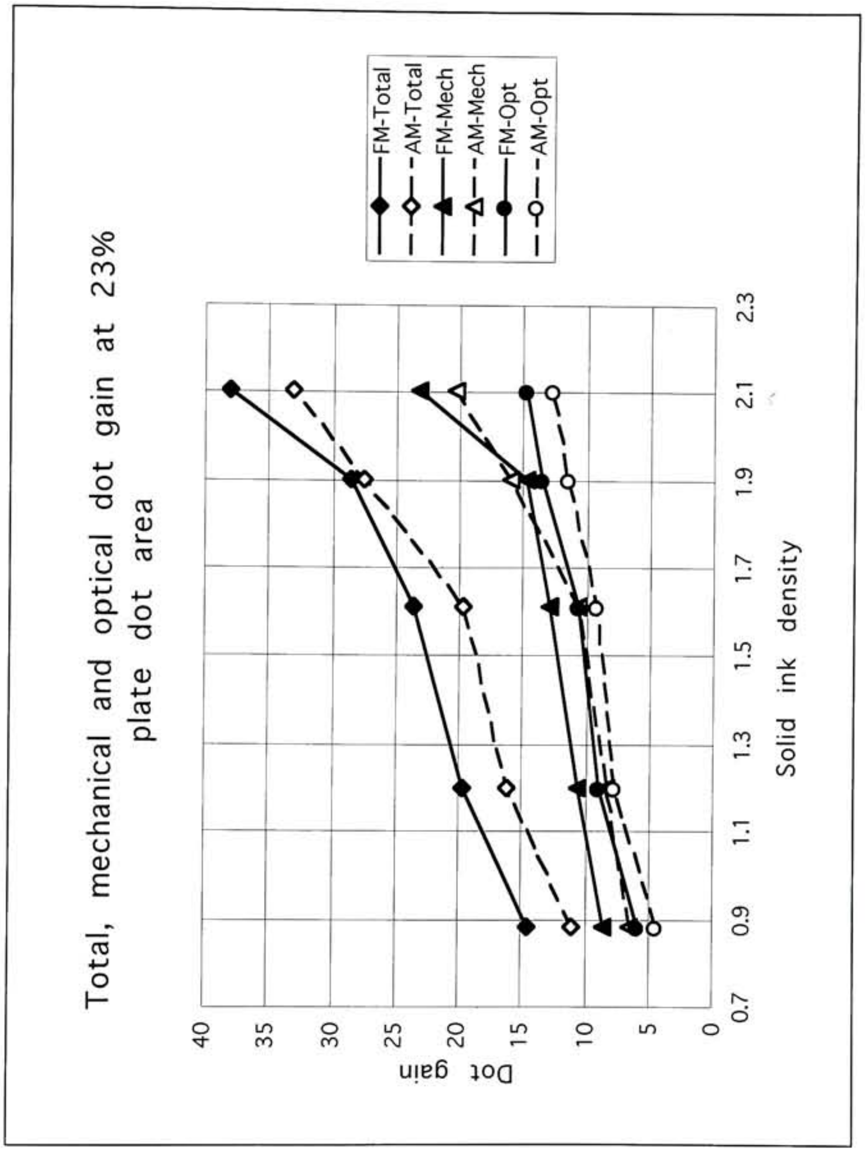


Figure A.9 Comparison of total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 23%.

Figure A.10 Comparison of total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 34%.

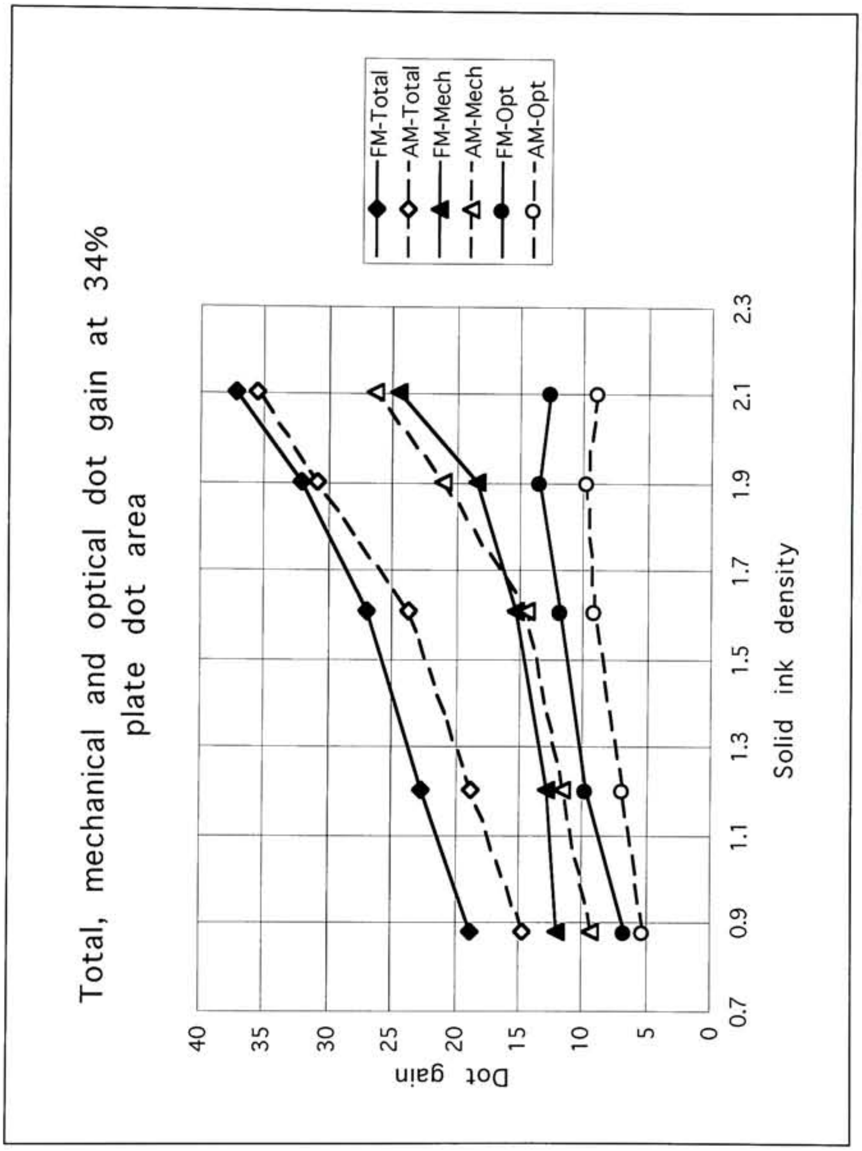


Figure A.10 Comparison of total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 34%.

Figure A.11 Comparison of total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 44%.

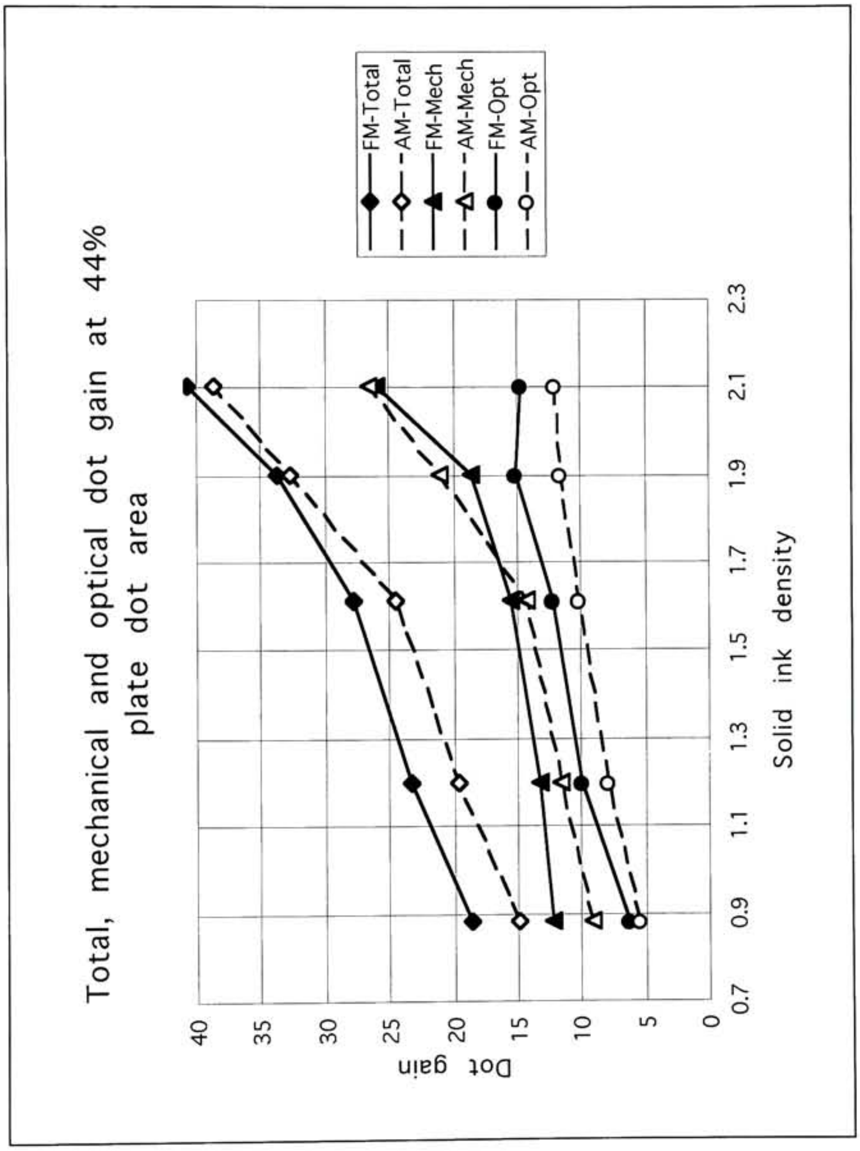


Figure A.11 Comparison of total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 44%.

Figure A.12 Comparison of total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 54%.

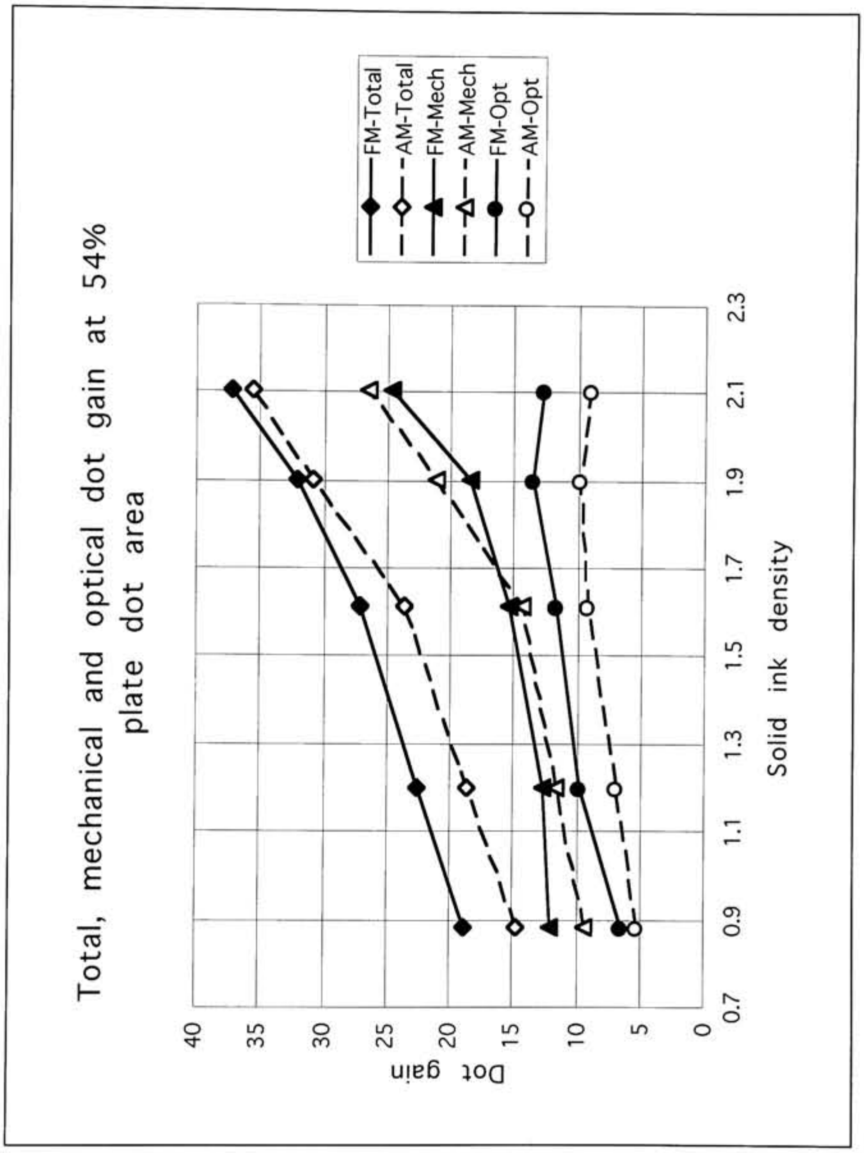


Figure A.12 Comparison of total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 54%.

Figure A.13 Comparison of total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 64%.

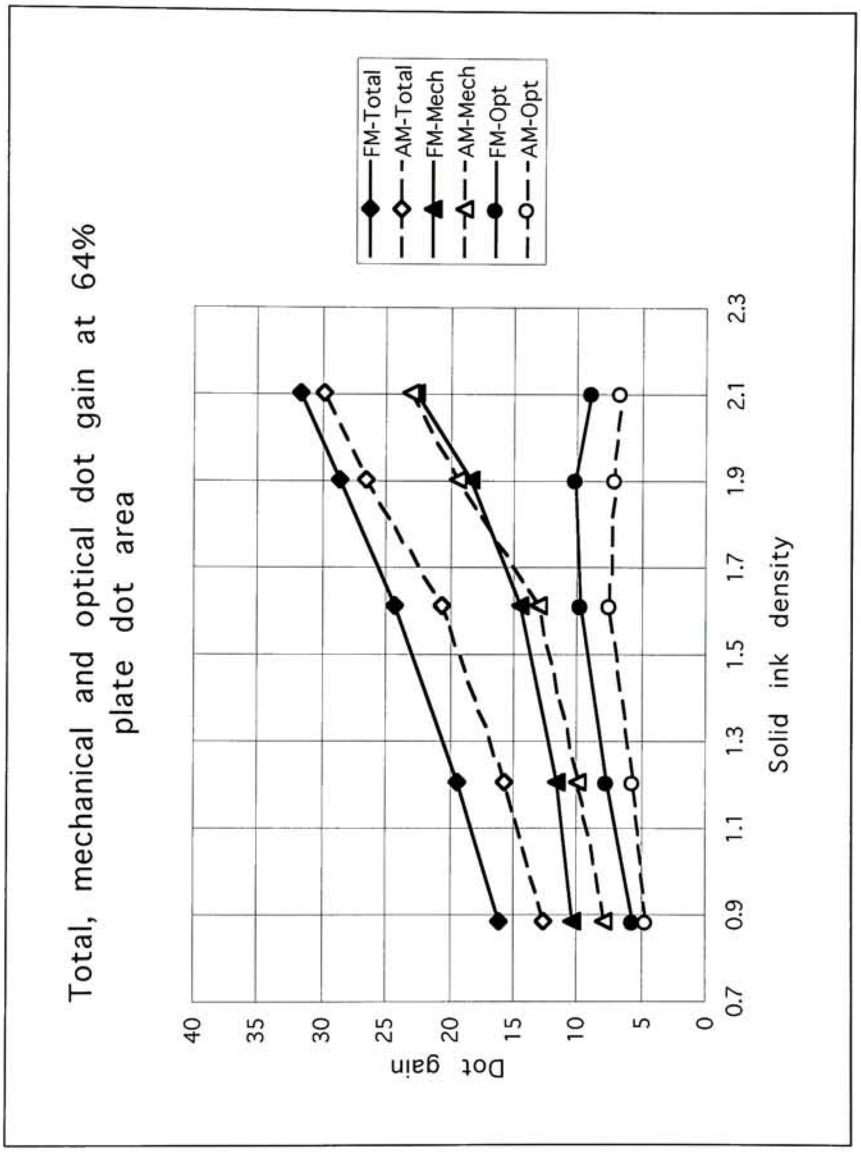


Figure A.13 Comparison of total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 64%.

Figure A.14 Comparison of total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 73%.

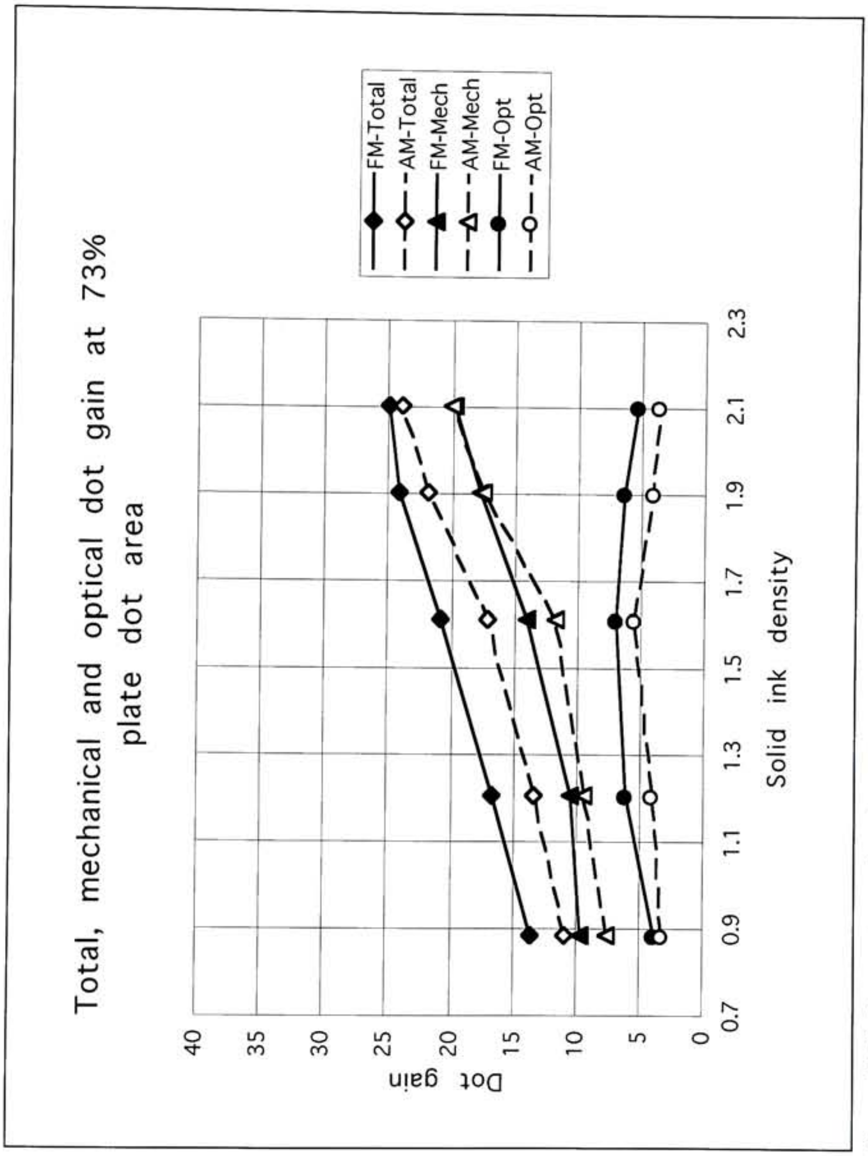


Figure A.14 Comparison of total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 73%.

Figure A.15 Comparison of total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 83%.

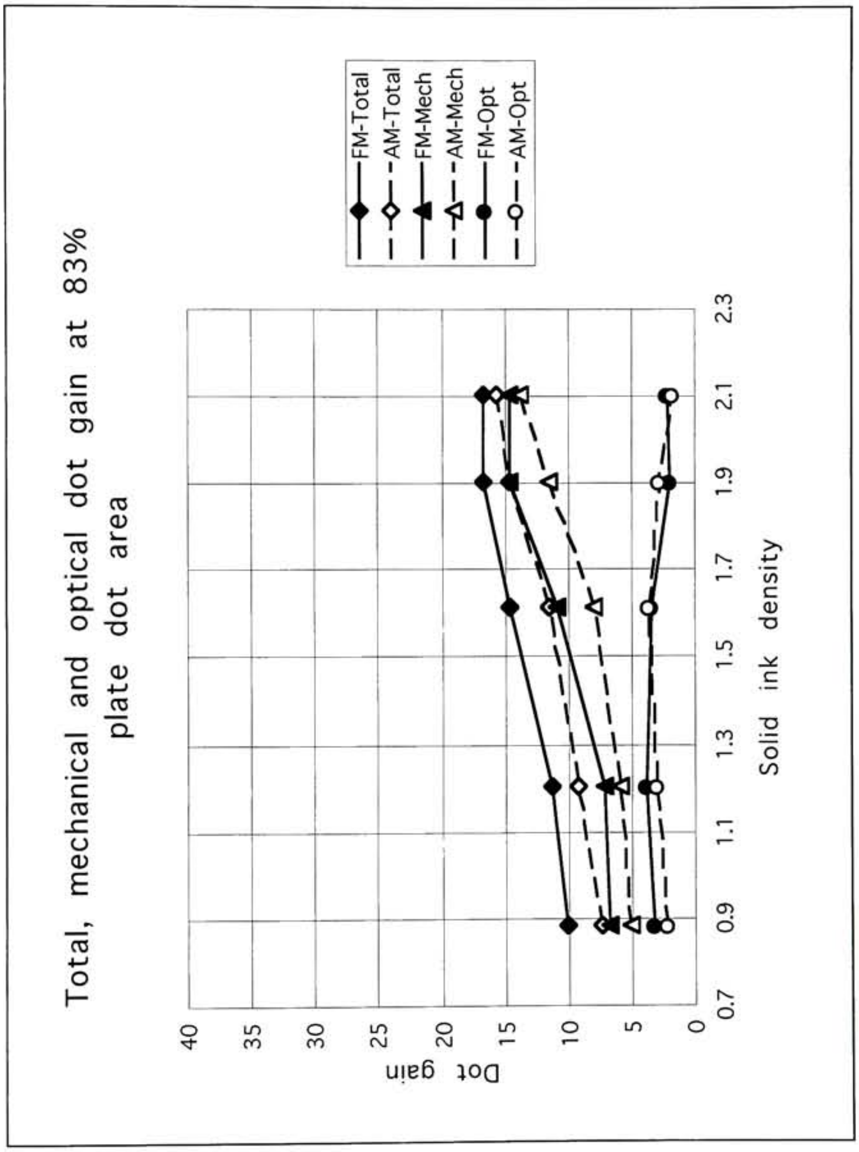


Figure A.15 Comparison of total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 83%.

Figure A.16 Comparison of total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 92%.

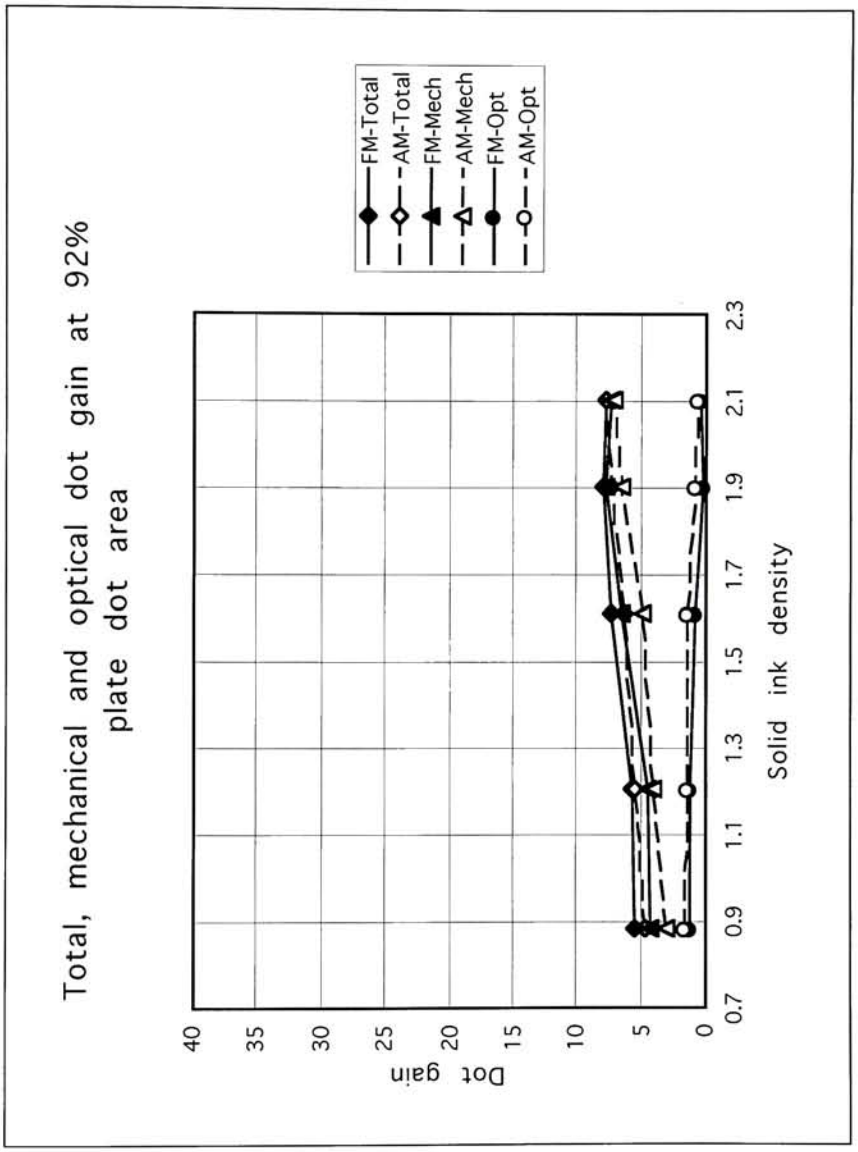


Figure A.16 Comparison of total, mechanical and optical dot gain of AM and FM screened tone scales, plate dot area 92%.

Table A.7 Variation from zero in transmission mode (% dot area) of Kimdura.

Kimdura, Variation from zero in transmission mode (20 x 20 mm area)

Sheet #	1	2	3	4	5	6	7
Variation	0.0	0.0	0.0	0.2	0.0	0.0	-0.4
(% dot area)	-0.3	0.2	-0.1	0.3	-0.1	0.0	0.0
	-0.2	-0.1	-0.1	0.2	0.0	0.2	-0.2
	0.1	-0.3	0.2	-0.1	-0.1	-0.1	0.0
	0.4	0.0	0.1	0.0	0.0	0.1	0.1
	0.2	-0.3	0.0	0.1	0.0	0.3	-0.3
	0.2	0.0	0.1	0.1	-0.2	0.1	-0.4
	-0.1	0.1	0.1	0.0	-0.2	0.1	0.0
	0.4	0.0	0.0	0.1	-0.1	0.2	-0.2
	-0.1	-0.1	0.2	0.0	-0.2	0.2	0.0

Table A.7 Variation in transmission mode % dot area of Kimdura, 20 x 20 mm area.

Appendix B

CCD captures of halftone dots in the Pixeldot target, CCD captures of AM and FM tone scales, Calculations of Core dot density

Table B.1 Digital counts representing the average ink reflectance of the halftone dots in the Pixeldot target, dot area 0.25, SID 0.9, 1.2, 1.6, 1.9, 2.1. Calculations of core dot density.

Raw Digital Counts Ink (Ink distribution of halftone dots)

Dot size µm	21µm	32µm	42µm	63µm	84µm	105µm	126µm	147µm		
Clustered dot	2x2	3x3	4x4	6x6	8x8	10x10	12x12	14x14	Kimdura	Dark Frame
SID 0.9	91	78	75	70	68	64	66	64	218	22
SID 1.2	85	71	63	58	53	51	47	46	216	22
SID 1.6	75	60	50	44	39	38	37	36	214	22
SID 1.9	67	45	40	34	33	32	31	31	216	22
SID 2.1	55	45	38	33	32	31	31	30	216	22

Digital Counts Ink (Dark frame Corrected)

Dot size	2x2	3x3	4x4	6x6	8x8	10x10	12x12	14x14	Kimdura
SID 0.9	69	56	53	48	46	42	44	42	196
SID 1.2	63	49	41	36	31	29	25	24	194
SID 1.6	53	38	28	22	17	16	15	14	192
SID 1.9	45	23	18	12	11	10	9	9	194
SID 2.1	33	23	16	11	10	9	9	8	194

Calculated Reflectance of the ink (Relative to Kimdura)

Dot size	2x2	3x3	4x4	6x6	8x8	10x10	12x12	14x14
SID 0.9	0.352	0.286	0.270	0.245	0.235	0.214	0.224	0.214
SID 1.2	0.325	0.253	0.211	0.186	0.160	0.149	0.129	0.124
SID 1.6	0.276	0.198	0.146	0.115	0.089	0.083	0.078	0.073
SID 1.9	0.232	0.119	0.093	0.062	0.057	0.052	0.046	0.046
SID 2.1	0.170	0.119	0.082	0.057	0.052	0.046	0.046	0.041

Conversion of reflectance values to Core dot density (Relative to Kimdura)

Dot size	2x2	3x3	4x4	6x6	8x8	10x10	12x12	14x14
SID 0.9	0.453	0.544	0.568	0.611	0.629	0.669	0.649	0.669
SID 1.2	0.488	0.598	0.675	0.731	0.796	0.825	0.890	0.908
SID 1.6	0.559	0.704	0.836	0.941	1.053	1.079	1.107	1.137
SID 1.9	0.635	0.926	1.033	1.209	1.246	1.288	1.334	1.334
SID 2.1	0.769	0.926	1.084	1.246	1.288	1.334	1.334	1.385

Table B.1 Digital counts representing the average ink reflectance of the halftone dots in the Pixeldot target and calculations of core dot density. Images were captured at x5 magnification, Image field of view 1 x 0.75 mm. Stemi SV 11 Microscope Zeiss Germany, Sony 3 CCD Color Video Camera, Model DXC-930P, RasterOps Framegrabber 640 x 480 pixels, Adobe Photoshop 3.0.

Figure B.1 Core dot density vs. dot size. Pixeldot target, dot area 0.25, printed at SID 0.9, 1.2, 1.6, 1.9, 2.1.

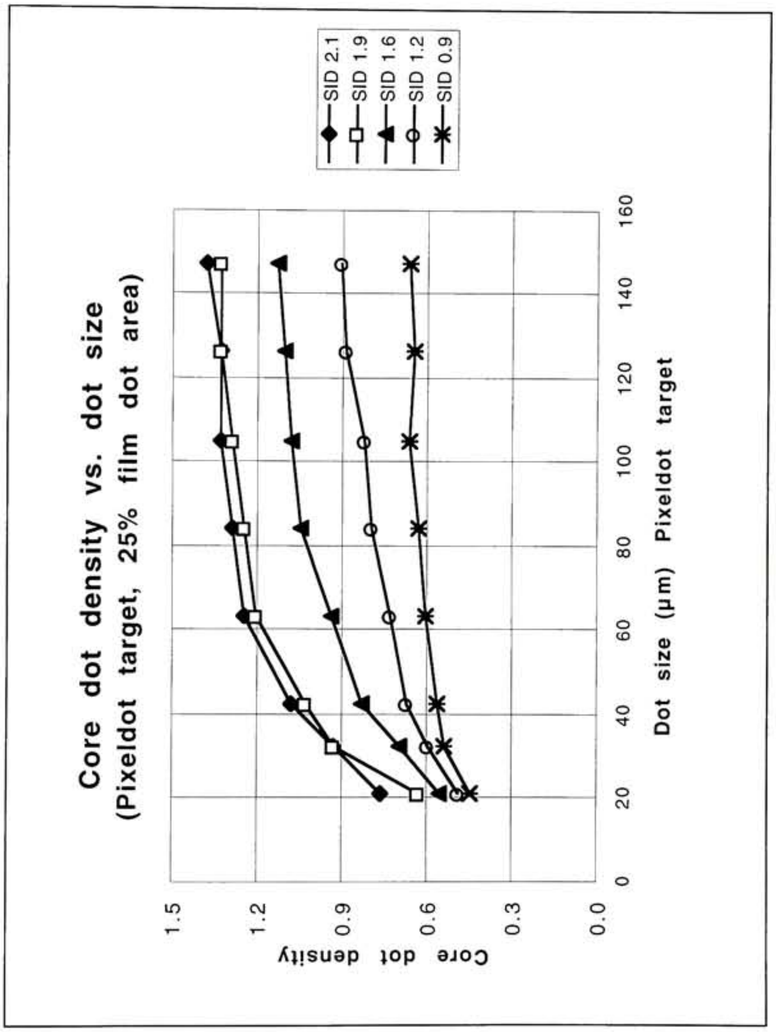


Figure B.1 Core dot density vs. dot size, Pixeldot target, dot area 0.25, SID 0.9, 1.2, 1.6, 1.9, 2.1.

Figure B.2 Core dot density vs. solid ink density. Pixeldot target, dot area 0.25, printed at SID 0.9, 1.2, 1.6, 1.9, 2.1.

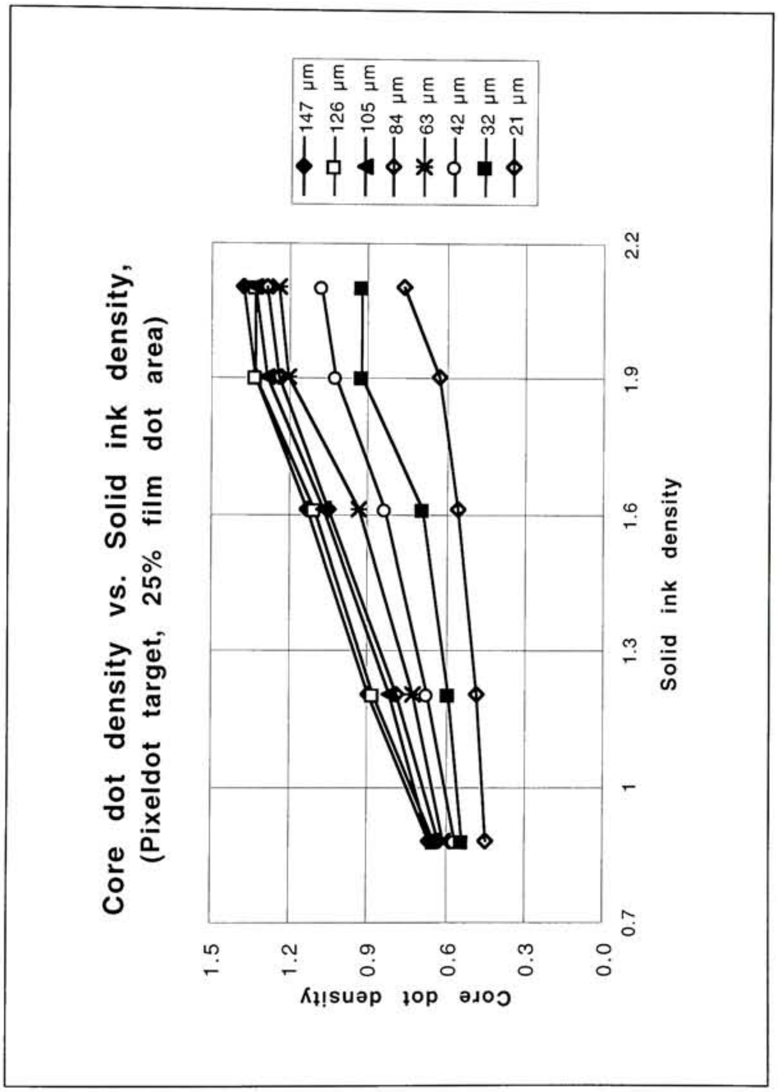


Figure B.2 Core dot density vs. solid ink density, Pixeldot target, dot area 0.25, SID 0.9, 1.2, 1.6, 1.9, 2.1.

Table B.2 Digital counts representing the average ink reflectance of the tints of the AM and FM halftone scales, printed at SID 1.2, 1.6, 1.9. Calculations of core dot density.

Raw Digital Counts Ink (Ink distribution of halftone dots)

Plate dot area	0.11	0.22	0.34	0.44	0.54	0.64	0.73	0.83	0.92	1.00	Kimdura
SID1.2-AM	68	55	48	44	40	39	38	37	35	33	213
SID1.2-FM	108	88	74	64	55	48	41	39	36	33	213
SID1.6-AM	57	45	40	36	35	33	31	29	28	26	211
SID1.6-FM	90	75	64	51	43	39	33	30	27	26	211
SID1.9-AM	49	38	34	32	31	29	28	27	25	24	214
SID1.9-FM	84	67	54	42	36	31	28	25	24	24	214

Digital Counts Ink (Dark frame Corrected)

Plate dot area	0.11	0.22	0.34	0.44	0.54	0.64	0.73	0.83	0.92	1.00	Dark Fr.
SID1.2-AM	46	33	26	22	18	17	16	15	13	11	22
SID1.2-FM	86	66	52	42	33	26	19	17	14	11	22
SID1.6-AM	35	23	18	14	13	11	9	7	6	4	22
SID1.6-FM	68	53	42	29	21	17	11	8	5	4	22
SID1.9-AM	27	16	12	10	9	7	6	5	3	2	22
SID1.9-FM	62	45	32	20	14	9	6	3	2	2	22

Calculated Reflectance Ink (Relative to unprinted Kimdura)

Plate dot area	0.11	0.22	0.34	0.44	0.54	0.64	0.73	0.83	0.92	1.00
SID1.2-AM	0.241	0.173	0.136	0.115	0.094	0.089	0.084	0.079	0.068	0.058
SID1.2-FM	0.450	0.346	0.272	0.220	0.173	0.136	0.099	0.089	0.073	0.058
SID1.6-AM	0.185	0.122	0.095	0.074	0.069	0.058	0.048	0.037	0.032	0.021
SID1.6-FM	0.360	0.280	0.222	0.153	0.111	0.090	0.058	0.042	0.026	0.021
SID1.9-AM	0.141	0.083	0.063	0.052	0.047	0.036	0.031	0.026	0.016	0.010
SID1.9-FM	0.323	0.234	0.167	0.104	0.073	0.047	0.031	0.016	0.010	0.010

Conversion of reflectance values to Core dot density (Relative to Kimdura)

Plate dot area	0.11	0.22	0.34	0.44	0.54	0.64	0.73	0.83	0.92	1.00
SID1.2-AM	0.618	0.763	0.866	0.939	1.026	1.051	1.077	1.105	1.167	1.240
SID1.2-FM	0.347	0.461	0.565	0.658	0.763	0.866	1.002	1.051	1.135	1.240
SID1.6-AM	0.732	0.915	1.021	1.130	1.163	1.235	1.322	1.431	1.498	1.674
SID1.6-FM	0.444	0.552	0.653	0.814	0.954	1.046	1.235	1.373	1.577	1.674
SID1.9-AM	0.852	1.079	1.204	1.283	1.329	1.438	1.505	1.584	1.806	1.982
SID1.9-FM	0.491	0.630	0.778	0.982	1.137	1.329	1.505	1.806	1.982	1.982

Table B.2 Digital counts representing the average ink reflectance of the halftone dots in the AM and FM halftone scales and calculations of core dot density. Images were captured at x5 magnification, Image field of view 1 x 0.75 mm. Stemi SV 11 Microscope Zeiss Germany, Sony 3 CCD Color Video Camera, Model DXC-930P, RasterOps Framegrabber 640 x 480 pixels, Adobe Photoshop 3.0.

Figure B.3 Core dot density of 150 lpi AM halftone scale, printed at SID 1.2, 1.6, 1.9.

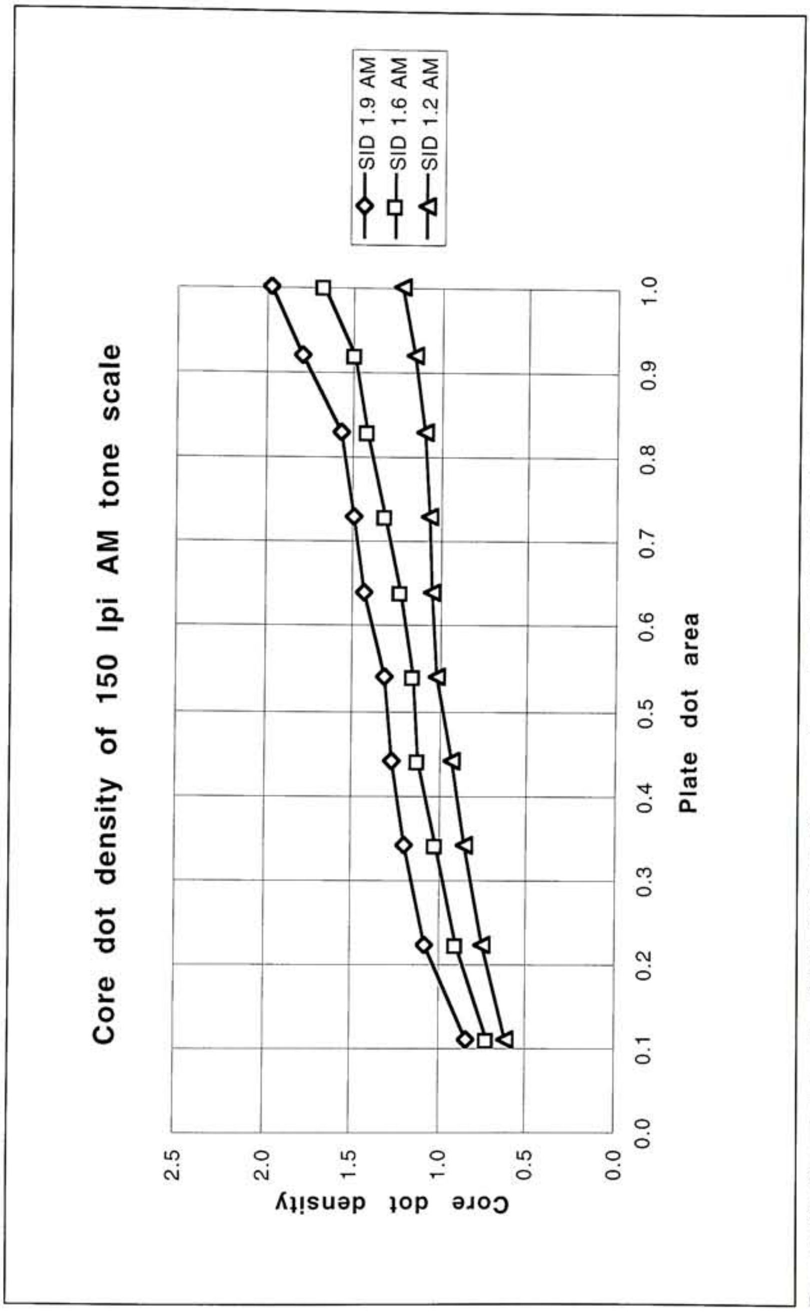


Figure B.3 Core dot density of AM 150lpi halftone scales, printed at SID 1.2, 1.6, 1.9.

Figure B.4 Core dot density of 21µm FM halftone scale, printed at SID 1.2, 1.6, 1.9.

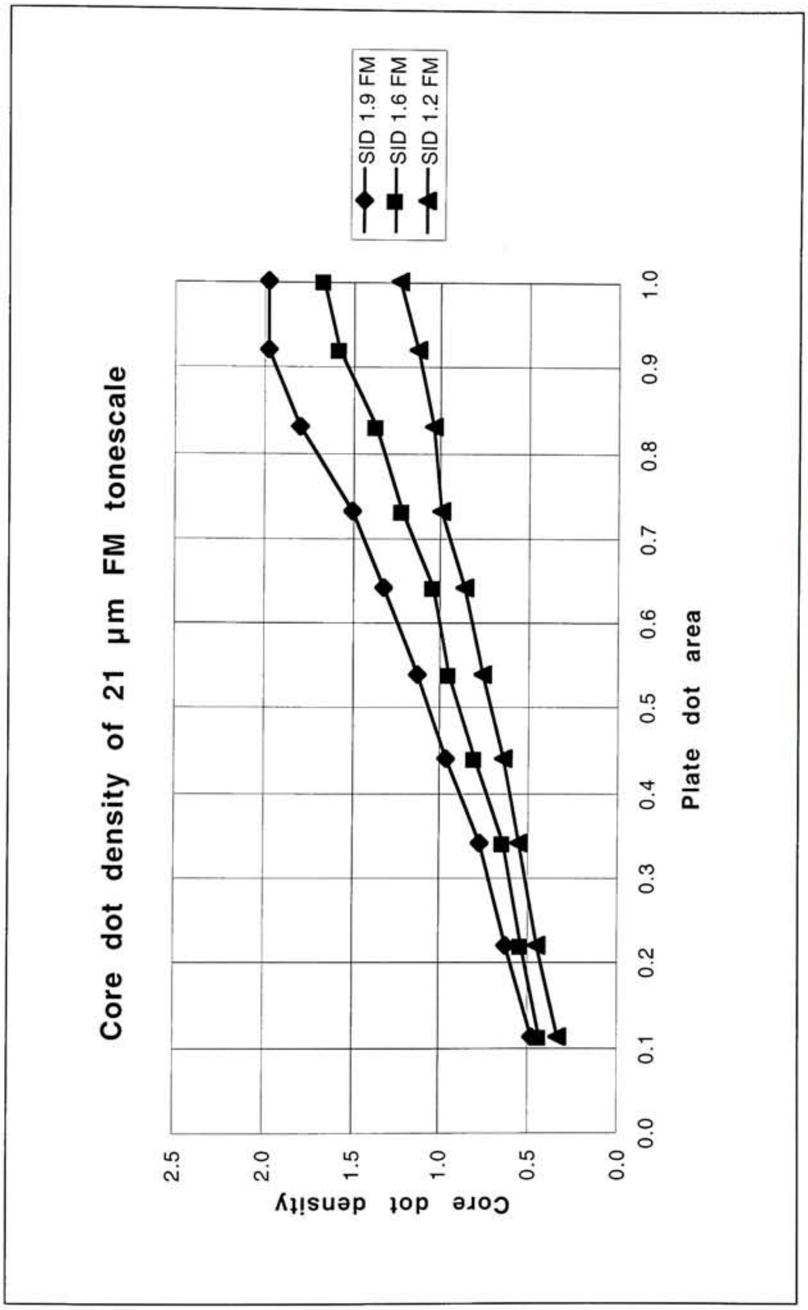
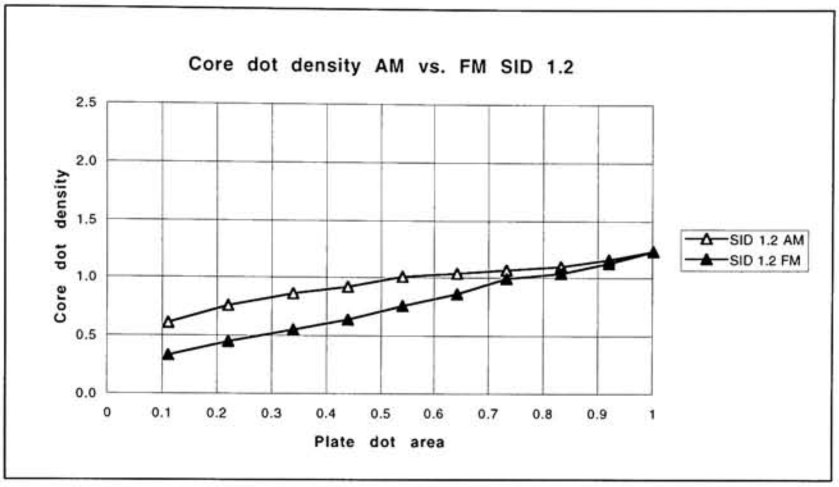
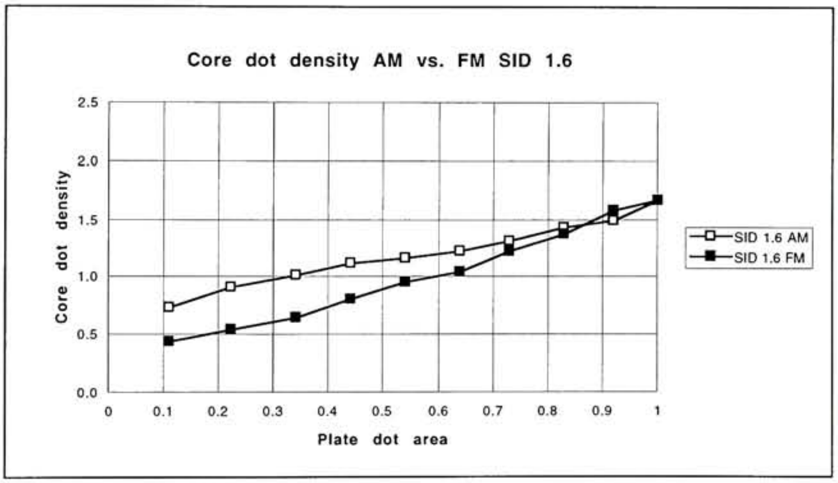


Figure B.4 Core dot density of FM 21µm halftone scales, printed at SID 1.2, 1.6, 1.9.

Figure B.5 Comparison of core dot density of AM and FM halftone scales, printed at SID 1.2, 1.6, 1.9.





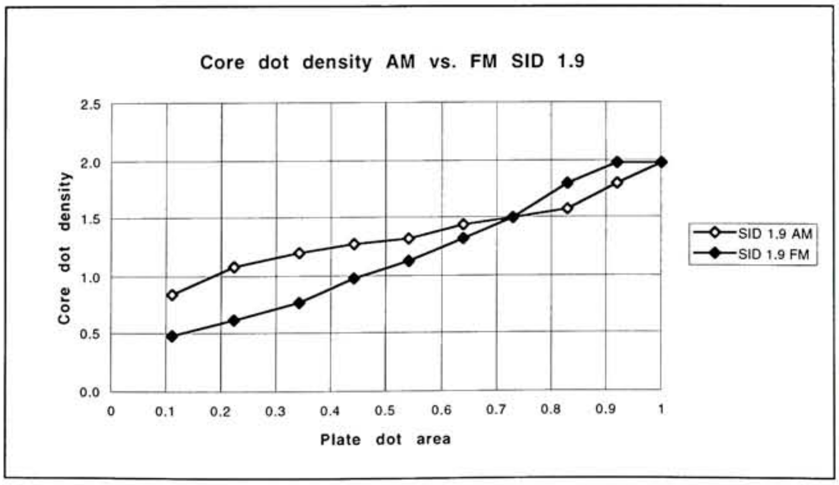


Figure B.5 Comparison of core dot density of AM and FM halftone scales, printed at SID 1.2, 1.6, 1.9.

Appendix C

Comparison of predicted tint density calculated by the Murray-Davies, the Yule-Nielsen and the modified Murray-Davies equation.

C. Comparison of predicted tint density as calculated from the Murray-Davies equation, the Yule-Nielsen equation and the modified Murray-Davies equation.

When studying the histograms of the CCD captured images of the AM and FM screened tone scales it is shown that both the reflectance of the ink and the reflectance of the substrate is a function of dot area. The average ink reflectance of the FM tints throughout the tone scale are higher than the average ink reflectance of the AM tints. In contrast, the average substrate reflectance of the FM tints is lower throughout the tone scale than the average substrate reflectance of the AM tints.

A comparison was performed between the original Murray-Davies equation (which assumes the reflectance of the ink and the reflectance of the substrate to be constant), the Yule-Nielsen equation and a modification of the original Murray-Davies equation. The modified Murray-Davies equation is modified in the sense that the reflectance of the ink and the reflectance of the substrate were values obtained from the histogram instead of using only the SID and paper density. At each dot area the average ink and the average substrate reflectance values were obtained from the histogram. See Table C.1–C.2, page 95–96. These values became the reflectance of the ink on the half tone dots (R_{ink}) and the reflectance of the substrate between the half tone dots (R_{sub}) to be used in the modified Murray-Davies equation:

$R_{t\,(a)} = R_{ink}\ a * R_{sub}(1\text{-}a)$.

The value of n in the Yule-Nielsen equation was estimated by regression analysis using the measured reflectance tint densities, the transmission dot area, the density of the unprinted substrate and the density of the solid. The value of n was then used in the Yule-Nielsen equation to calculate the predicted tint density for each tonal area.

The predicted tint densities by the Murray-Davies equation were calculated using the transmission dot area measurements, the density of the unprinted substrate and the density of the solid.

Fig. C.1–C.4 show that the errors of the modified Murray-Davies equation are reduced to almost that of the Yule-Nielsen equation (at the lower and midtone dot areas). Therefore the failure of the original Murray-Davies equation is due in part to the fact that the reflectance of the ink and the reflectance of the paper change as functions of dot area.

At dot areas of 0.6 and higher there are increasing difficulties to determine the average substrate reflectance from the histogram, especially for the FM tone scales. In Fig. C.1–C.4, data points of high dot areas are excluded when the average reflectance of the substrate could not be determined from the histogram.

Note that the density of the solid predicted by the Modified Murray-Davies equation is higher than the measured solid ink density for SID 1.2 as well as SID 1.6. The difference in SID between the modified Murray-Davies equation and the Yule-Nielsen and Murray-Davies equation could be due to a calibration difference between the densitometer and the CCD camera.

Table C.1 Digital counts representing average ink reflectance and average substrate reflectance of AM and FM tone scales, printed at SID 1.2, 1.6.

Raw Digital Counts Ink (Ink distribution of halftone dots)

Plate dot area	0.11	0.22	0.34	0.44	0.54	0.64	0.73	0.83	0.92	1.00
SID1.2-AM	68	55	48	44	40	39	38	37	35	33
SID1.2-FM	108	88	74	64	55	48	41	39	36	33
SID1.6-AM	57	45	40	36	35	33	31	29	28	26
SID1.6-FM	90	75	64	51	43	39	33	30	27	26

Kimdura
213
213
211
211

Raw Digital Counts Kimdura (substrate between the halftone dots)

Plate dot area	0.11	0.22	0.34	0.44	0.54	0.64	0.73	0.83	0.92	1.00
SID1.2-AM	197	180	168	154	146	134	124	112	96	---
SID1.2-FM	190	170	148	127	115	101	86	---	---	---
SID1.6-AM	187	171	156	141	128	117	107	92	---	---
SID1.6-FM	179	159	133	112	96	78	---	---	---	---

Dark Fr.
22
22
22
22

Digital Counts Ink (Dark frame Corrected)

Plate dot area	0.11	0.22	0.34	0.44	0.54	0.64	0.73	0.83	0.92	1.00
SID1.2-AM	46	33	26	22	18	17	16	15	13	11
SID1.2-FM	86	66	52	42	33	26	19	17	14	11
SID1.6-AM	35	23	18	14	13	11	9	7	6	4
SID1.6-FM	68	53	42	29	21	17	11	8	5	4

Digital Counts Kimdura (Dark frame corrected)

Plate dot area	0.11	0.22	0.34	0.44	0.54	0.64	0.73	0.83	0.92	1.00
SID1.2-AM	175	158	146	132	124	112	102	90	74	---
SID1.2-FM	168	148	126	105	93	79	64	---	---	---
SID1.6-AM	165	149	134	119	106	95	85	70	---	---
SID1.6-FM	157	137	111	90	74	56	---	---	---	---

Table C.1 Digital counts representing the average ink reflectance and the average substrate reflectance. Images were captured at x5 magnification, Image field of view 1 x 0.75 mm. Stemi SV 11 Microscope Zeiss Germany, Sony 3 CCD Color Video Camera, Model DXC-930P, RasterOps Framegrabber 640 x 480 pixels, Adobe Photoshop 3.0.

Table C.2 Calculations of average ink reflectance and average substrate reflectance of AM and FM tone scales, SID 1.2, 1.6. Calculations of tint reflectance and of tint density using the modified Murray-Davies equation.

Calculated Reflectance Ink, Rink (relative to unprinted Kimdura)

Plate dot area	0.11	0.22	0.34	0.44	0.54	0.64	0.73	0.83	0.92	1.00
SID1.2-AM	0.241	0.173	0.136	0.115	0.094	0.089	0.084	0.079	0.068	0.058
SID1.2-FM	0.450	0.346	0.272	0.220	0.173	0.136	0.099	0.089	0.073	0.058
SID1.6-AM	0.185	0.122	0.095	0.074	0.069	0.058	0.048	0.037	0.032	0.021
SID1.6-FM	0.360	0.280	0.222	0.153	0.111	0.090	0.058	0.042	0.026	0.021

Calculated Reflectance Kimdura, Rsub (relative to unprinted Kimdura)

Plate dot area	0.11	0.22	0.34	0.44	0.54	0.64	0.73	0.83	0.92	1.00
SID1.2-AM	0.916	0.827	0.764	0.691	0.649	0.586	0.534	0.471	0.387	—
SID1.2-FM	0.880	0.775	0.660	0.550	0.487	0.414	0.335	—	—	—
SID1.6-AM	0.873	0.788	0.709	0.630	0.561	0.503	0.450	0.370	—	—
SID1.6-FM	0.831	0.725	0.587	0.476	0.392	0.296	—	—	—	—

Transmission dot area

Plate dot area	0.11	0.22	0.34	0.44	0.54	0.64	0.73	0.83	0.92	1.00
SID1.2-AM	0.172	0.311	0.444	0.563	0.666	0.747	0.831	0.895	0.960	1.000
SID1.2-FM	0.188	0.330	0.460	0.576	0.669	0.757	0.837	0.899	0.965	1.000
SID1.6-AM	0.193	0.334	0.470	0.589	0.693	0.778	0.854	0.914	0.969	1.000
SID1.6-FM	0.205	0.353	0.482	0.599	0.694	0.786	0.872	0.936	0.986	1.000

Modified Murray-Davies equation, Rt(a)=a*Rink+(1-a)Rsub
Reflectance Calculations, (Ink + Paper), predicted tint reflectance

Plate dot area	0.11	0.22	0.34	0.44	0.54	0.64	0.73	0.83	0.92	1.00
SID1.2-AM	0.800	0.624	0.485	0.367	0.280	0.215	0.160	0.120	0.081	0.058
SID1.2-FM	0.799	0.633	0.481	0.360	0.277	0.204	0.138	0.114	0.082	0.058
SID1.6-AM	0.740	0.566	0.421	0.302	0.220	0.157	0.106	0.066	0.042	0.021
SID1.6-FM	0.734	0.568	0.411	0.283	0.197	0.134	0.089	0.059	0.030	0.021

Modified Murray-Davies equation
Density Calculations, predicted tint density

Plate dot area	0.11	0.22	0.34	0.44	0.54	0.64	0.73	0.83	0.92	1.00
SID1.2-AM	0.097	0.205	0.314	0.436	0.553	0.668	0.796	0.922	1.092	1.240
SID1.2-FM	0.098	0.198	0.317	0.444	0.558	0.691	0.861	—	—	1.240
SID1.6-AM	0.131	0.247	0.376	0.519	0.658	0.804	0.973	1.182	—	1.674
SID1.6-FM	0.134	0.246	0.386	0.548	0.706	0.873	—	—	—	1.674

Table C.2 Images captured at x5 magnification, Image field of view 1 x 0.75 mm. Stemi SV 11 Microscope Zeiss Germany, Sony 3 CCD Color Video Camera, Model DXC-930P, RasterOps Framegrabber 640 x 480 pixels, Adobe Photoshop 3.0.

Table C.3, Figure C.1 Comparison of predicted tint density calculated using the Murray-Davies, the Yule-Nielsen and the modified Murray-Davies equation, AM tone scale SID 1.2.

SID 1.2 AM	Predicted tint density			
Plate dot area	Dt meas.	Dt M-D	Dt Y-N	Dt Mod. M-D
0.000	0.000	0.000	0.000	0.000
0.117	0.103	0.076	0.095	0.097
0.227	0.196	0.148	0.184	0.205
0.339	0.288	0.231	0.284	0.314
0.446	0.394	0.322	0.391	0.436
0.548	0.501	0.419	0.501	0.553
0.648	0.600	0.514	0.606	0.668
0.737	0.723	0.642	0.738	0.796
0.834	0.859	0.773	0.862	0.922
0.920	1.026	0.966	1.023	1.092
1.000	1.149	1.149	1.149	1.240
			n=1.37	

Table C.3 Comparison of predicted tint density calculated for AM tone scale, SID 1.2.

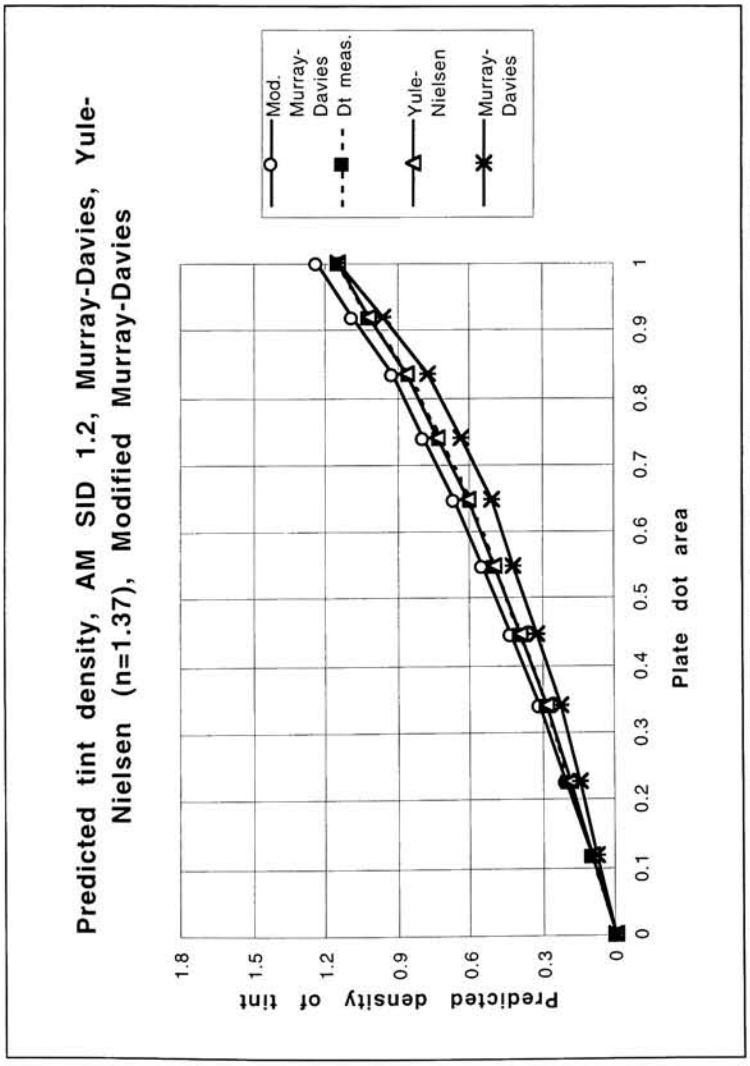


Figure C.1 Comparison of predicted tint density calculated for AM tone scale, SID 1.2.

Table C.4, Figure C.2 Comparison of predicted tint density calculated using the Murray-Davies, the Yule-Nielsen and the modified Murray-Davies equation, FM tone scale SID 1.2.

SID 1.2 FM	Predicted tint density			
Plate dot area	Dt meas.	Dt M-D	Dt Y-N	Dt Mod. M-D
0	0.000	0.000	0.000	0.000
0.111	0.113	0.083	0.113	0.098
0.223	0.215	0.159	0.212	0.198
0.335	0.318	0.242	0.318	0.317
0.442	0.430	0.333	0.430	0.444
0.541	0.543	0.422	0.535	0.558
0.640	0.649	0.528	0.651	0.691
0.732	0.784	0.653	0.779	0.847
0.826	0.898	0.784	0.897	---
0.920	1.039	0.986	1.052	---
1.000	1.151	1.151	1.151	1.240
			n=1.55	

Table C.4 Comparison of predicted tint density calculated for FM tone scale, SID 1.2.

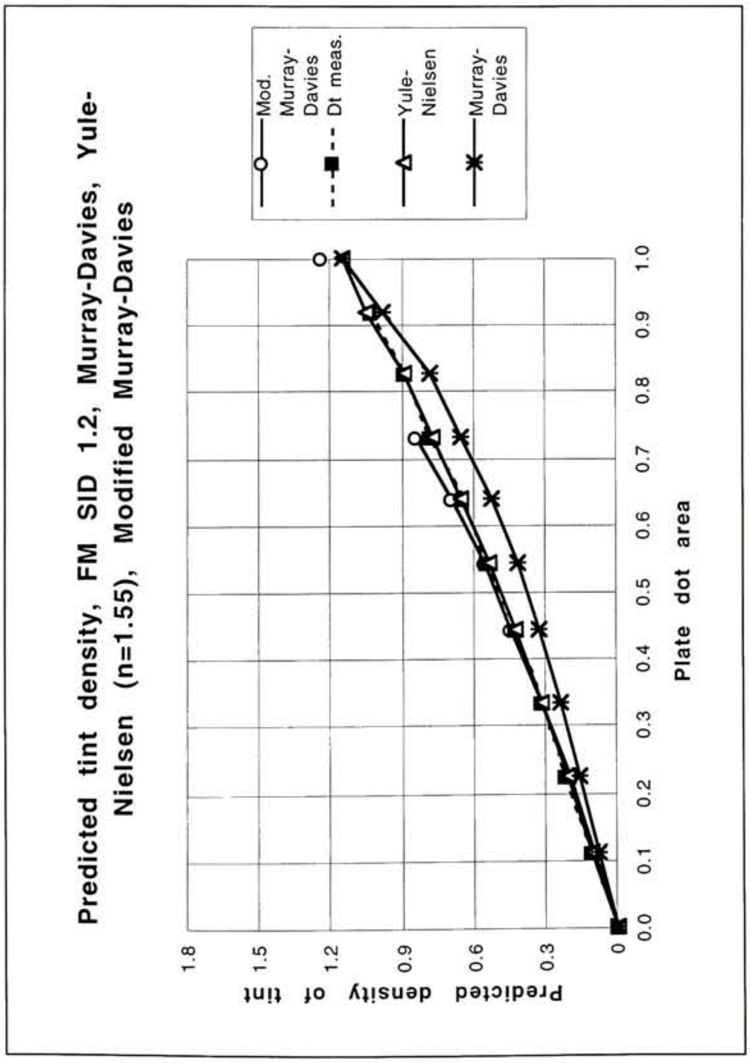


Figure C.2 Comparison of predicted tint density calculated for FM tone scale, SID 1.2.

Table C.5, Figure C.3 Comparison of predicted tint density calculated using the Murray-Davies, the Yule-Nielsen and the modified Murray-Davies equation, AM tone scale SID 1.6.

SID 1.6 AM	Predicted tint density			
Plate dot area	Dt meas.	Dt M-D	Dt Y-N	Dt Mod. M-D
0.000	0.000	0.000	0.000	0.000
0.117	0.125	0.090	0.120	0.131
0.227	0.232	0.171	0.225	0.247
0.339	0.351	0.265	0.347	0.376
0.446	0.485	0.369	0.479	0.519
0.548	0.626	0.487	0.623	0.658
0.648	0.772	0.613	0.772	0.804
0.737	0.933	0.769	0.945	0.973
0.834	1.121	0.953	1.129	1.182
0.920	1.352	1.234	1.362	—
1.000	1.551	1.550	1.550	1.674
			n=1.41	

Table C.5 Comparison of predicted tint density calculated for AM tone scale, SID 1.6.

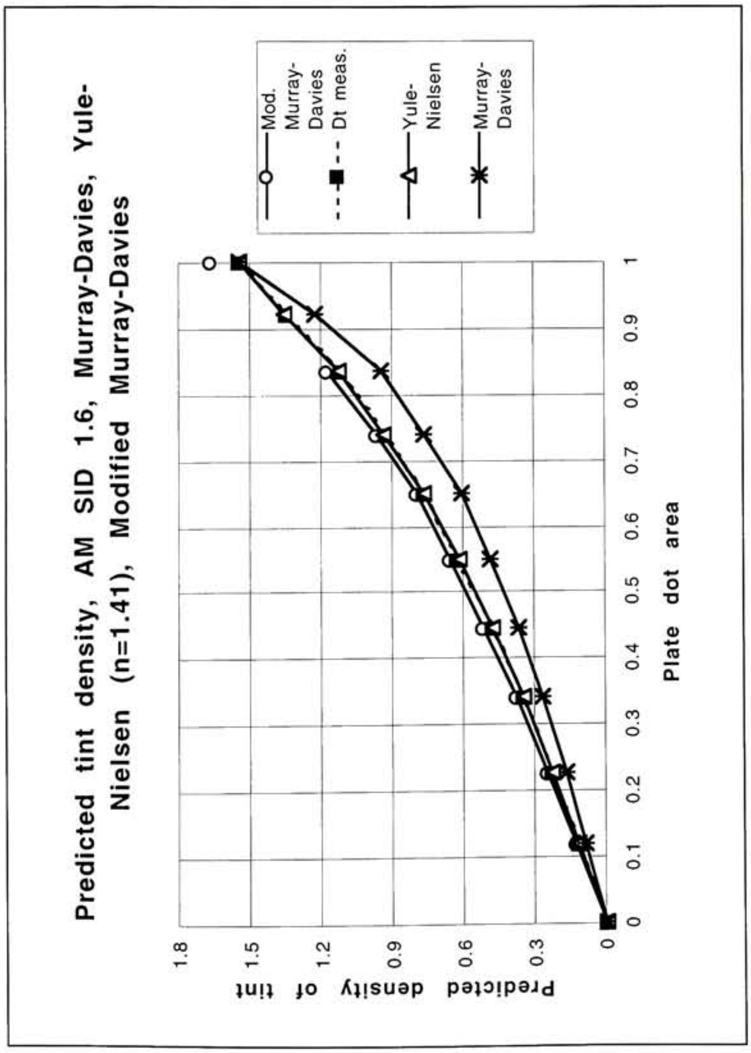


Figure C.3 Comparison of predicted tint density calculated for AM tone scale, SID 1.6.

Table C.6, Figure C.4 Comparison of predicted tint density calculated using the Murray-Davies, the Yule-Nielsen and the modified Murray-Davies equation, FM tone scale SID 1.6.

SID 1.6 FM	Predicted tint density			
Plate dot area	Dt meas.	Dt M-D	Dt Y-N	Dt Mod. M-D
0.000	0.000	0.000	0.000	0.000
0.111	0.135	0.096	0.142	0.134
0.223	0.258	0.182	0.266	0.246
0.335	0.386	0.274	0.395	0.386
0.442	0.524	0.379	0.536	0.548
0.541	0.677	0.487	0.677	0.706
0.640	0.848	0.626	0.846	0.873
0.732	1.071	0.815	1.051	—
0.826	1.259	1.042	1.255	—
0.920	1.465	1.374	1.469	—
1.000	1.543	1.543	1.543	1.674
			n=1.63	

Table C.6 Comparison of predicted tint density calculated for FM tone scale, SID 1.6.

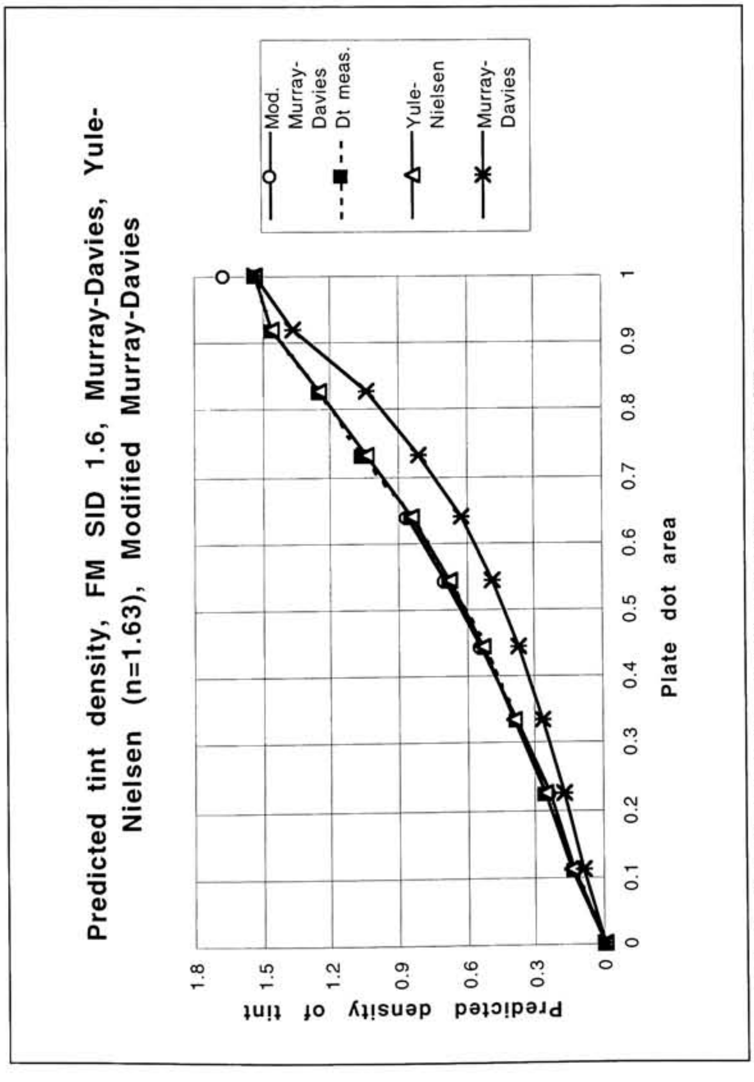
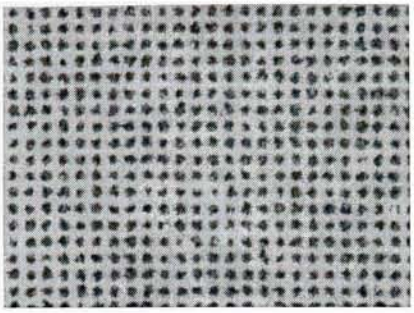


Figure C.4 Predicted tint density calculated for FM tone scale, SID 1.6.

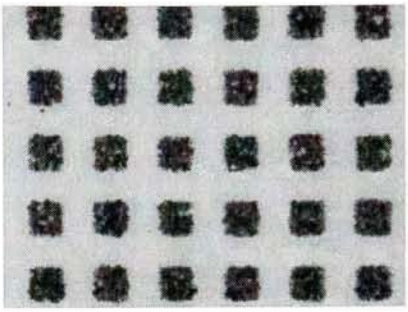
Appendix D

CCD captures of Pixeldot target,
CCD captures of AM and FM screened tonescales.

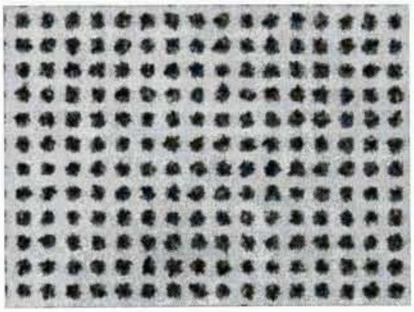
Fig. D.1 CCD captured images of Pixeldot target, dot area 0.25, SID 0.9.



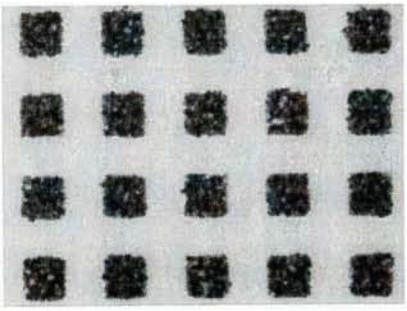
2 x 2, 21 μm dot, SID 0.9



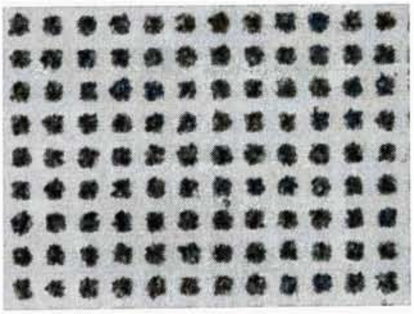
8 x 8, 84 μm, SID 0.9



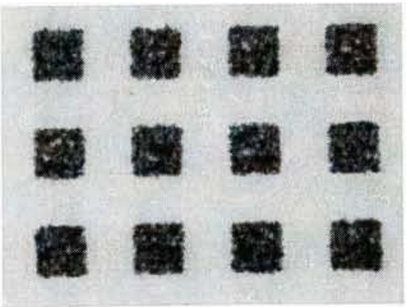
3 x 3, 32 μm, SID 0.9



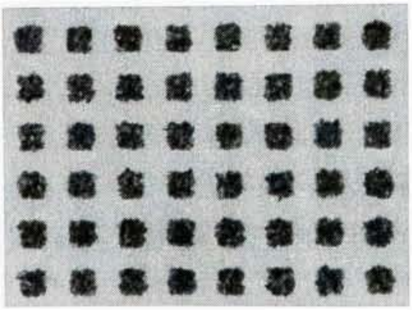
10 x 10, 105 μm, SID 0.9



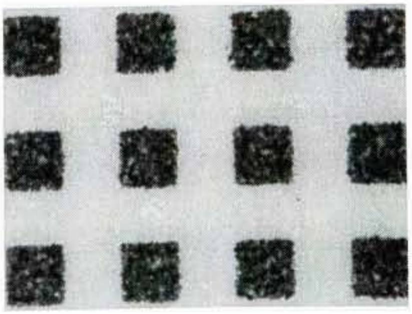
4 x 4, 42 μm, SID 0.9



12 x 12, 126 μm, SID 0.9



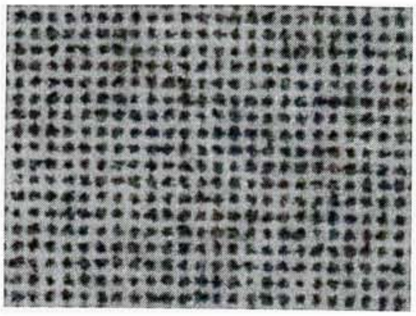
6 x 6, 63 μm, SID 0.9



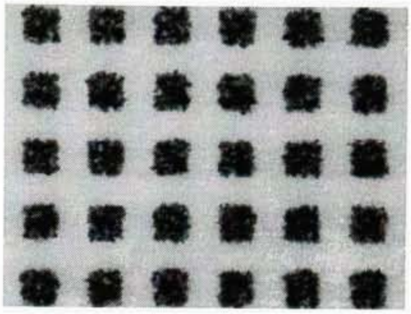
14 x 14, 147 μm , SID 0.9

Images were captured at x5 magnification, Image field of view 1 x 0.75 mm. Stemi SV 11 Microscope Zeiss Germany, Sony 3 CCD Color Video Camera, Model DXC-930P, RasterOps Framegrabber 640 x 480 pixels, Adobe Photoshop 3.0.

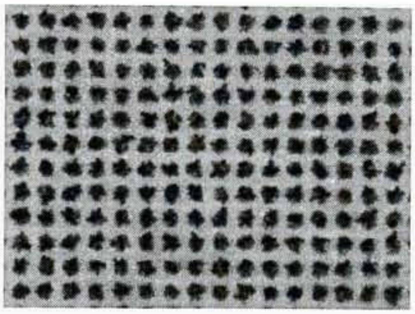
Fig. D.2 CCD captured images of Pixeldot target, dot area 0.25, SID 1.2.



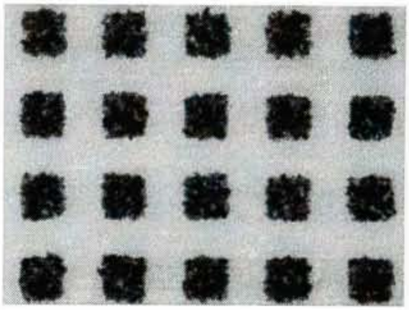
2 x 2, 21 µm dot, SID 1.2



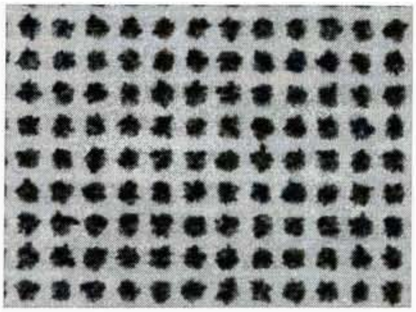
8 x 8, 84 µm, SID 1.2



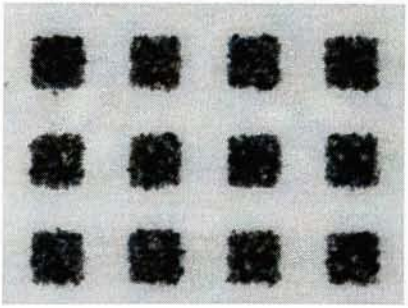
3 x 3, 32 µm, SID 1.2



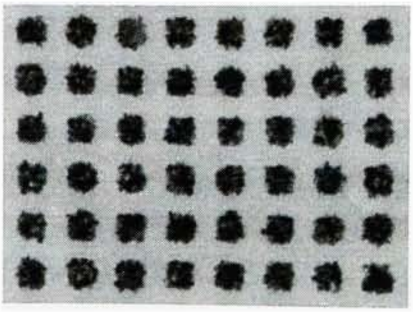
10 x 10, 105 µm, SID 1.2



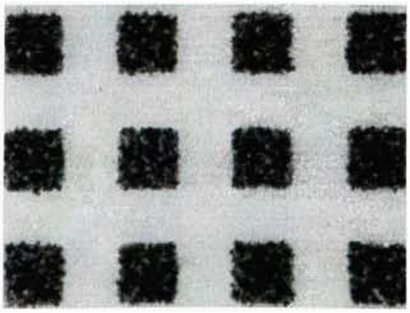
4 x 4, 42 µm, SID 1.2



12 x 12, 126 µm, SID 1.2



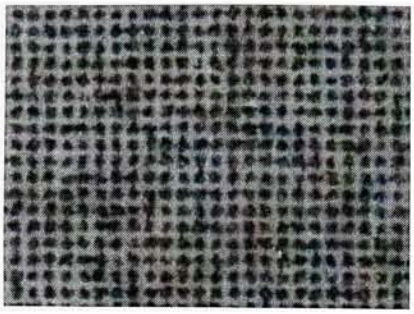
6 x 6, 63 µm, SID 1.2



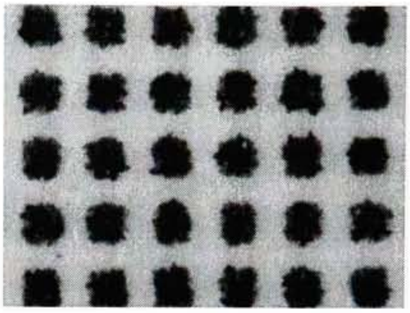
14 x 14, 147 µm , SID 1.2

Images were captured at x5 magnification, Image field of view 1 x 0.75 mm. Stemi SV 11 Microscope Zeiss Germany, Sony 3 CCD Color Video Camera, Model DXC-930P, RasterOps Framegrabber 640 x 480 pixels, Adobe Photoshop 3.0.

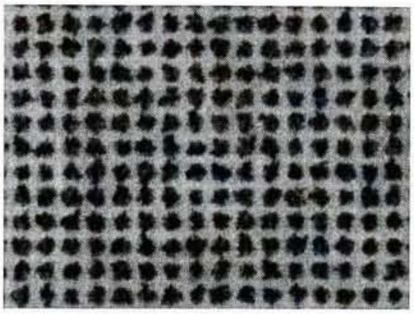
Fig. D.3 CCD captured images of Pixeldot target, dot area 0.25, SID 1.6.



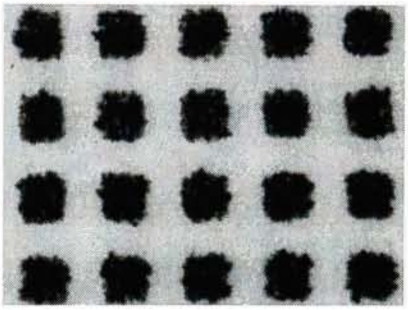
2 x 2, 21 µm dot, SID 1.6



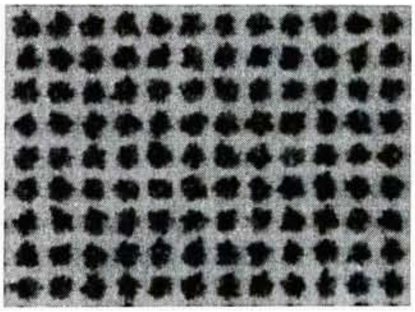
8 x 8, 84 µm, SID 1.6



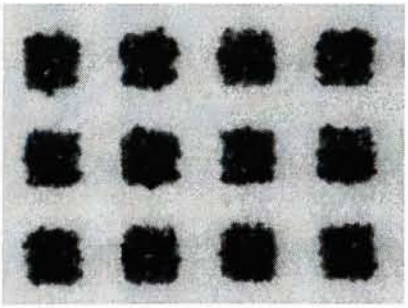
3 x 3, 32 µm, SID 1.6



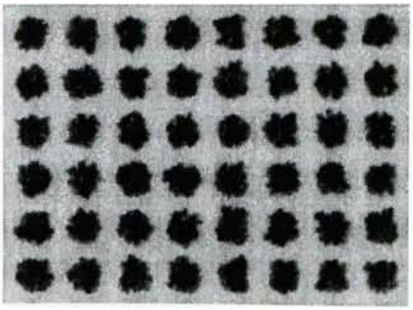
10 x 10, 105 µm, SID 1.6



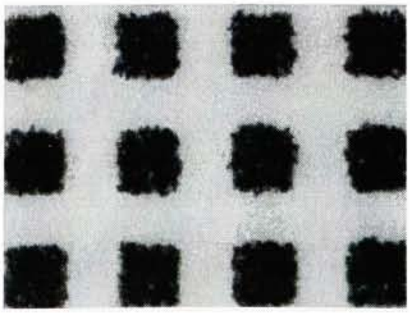
4 x 4, 42 µm, SID 1.6



12 x 12, 126 µm, SID 1.6



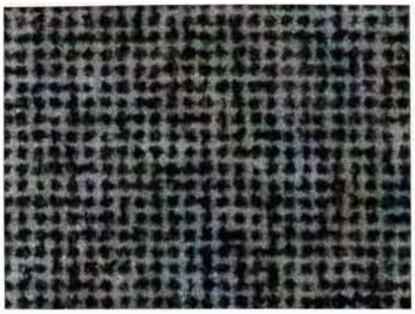
6 x 6, 63 µm, SID 1.6



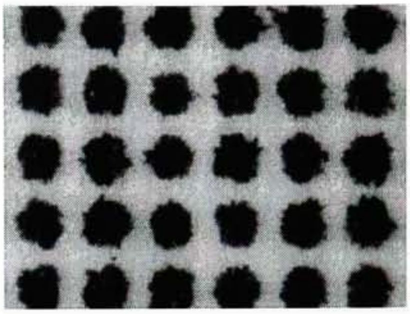
14 x 14, 147 µm , SID 1.6

Images were captured at x5 magnification, Image field of view 1 x 0.75 mm. Stemi SV 11 Microscope Zeiss Germany, Sony 3 CCD Color Video Camera, Model DXC-930P, RasterOps Framegrabber 640 x 480 pixels, Adobe Photoshop 3.0.

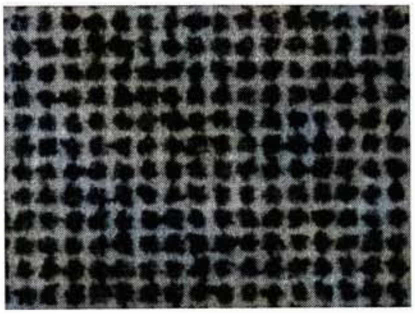
Fig. D.4 CCD captured images of Pixeldot target, dot area 0.25, SID 1.9.



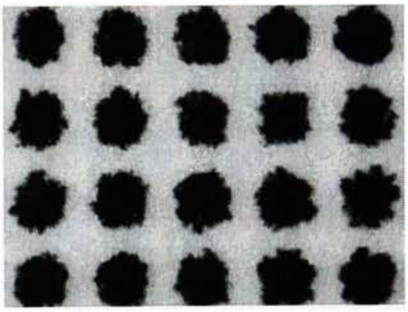
2 x 2, 21 µm dot, SID 1.9



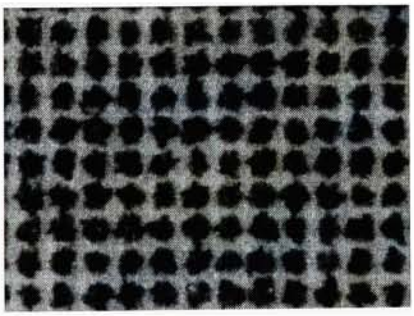
8 x 8, 84 µm, SID 1.9



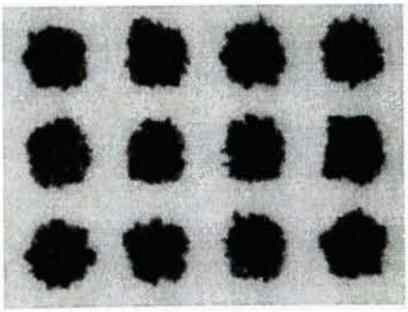
3 x 3, 32 µm, SID 1.9



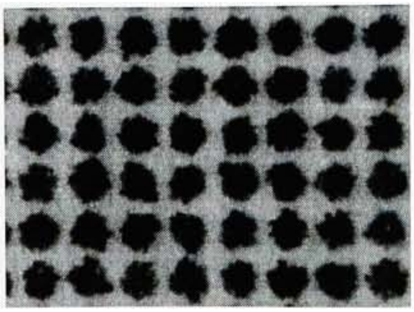
10 x 10, 105 µm, SID 1.9



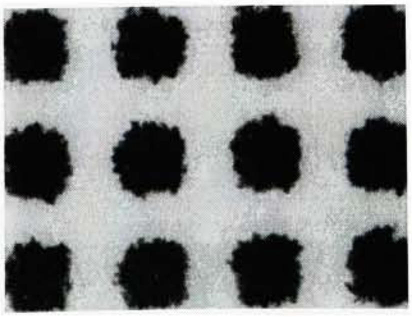
4 x 4, 42 µm, SID 1.9



12 x 12, 126 µm, SID 1.9



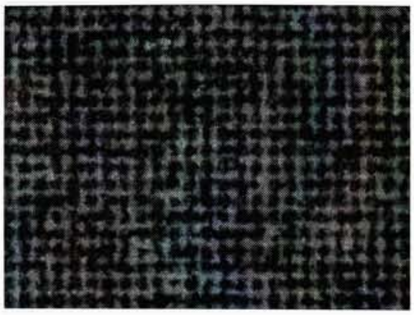
6 x 6, 63 µm, SID 1.9



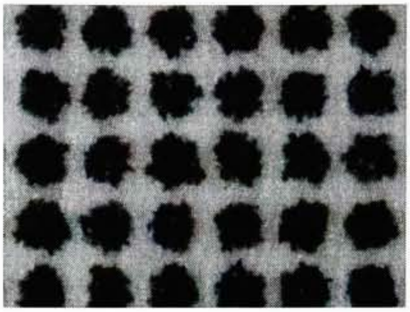
14 x 14, 147 µm , SID 1.9

Images were captured at x5 magnification, Image field of view 1 x 0.75 mm. Stemi SV 11 Microscope Zeiss Germany, Sony 3 CCD Color Video Camera, Model DXC-930P, RasterOps Framegrabber 640 x 480 pixels, Adobe Photoshop 3.0.

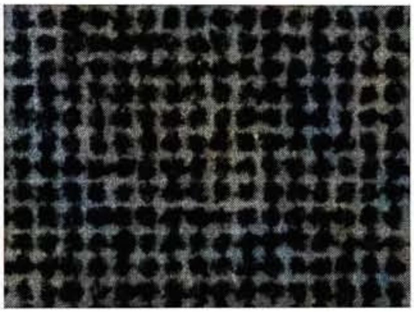
Fig. D.5 CCD captured images of Pixeldot target, dot area 0.25, SID 2.1.



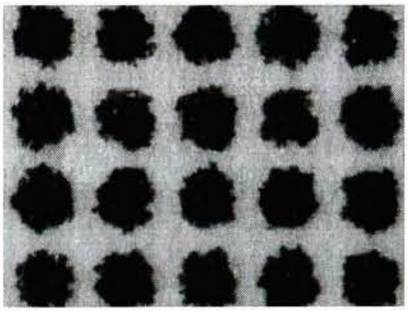
2 x 2, 21 µm dot, SID 2.1



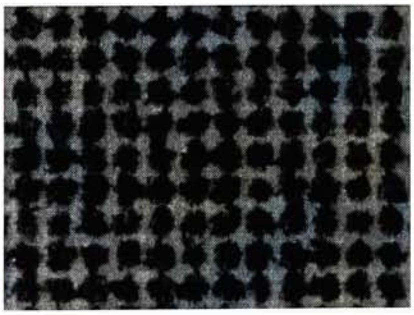
8 x 8, 84 µm, SID 2.1



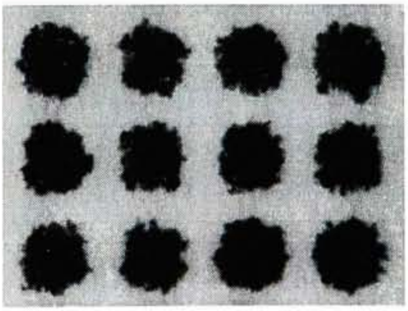
3 x 3, 32 µm, SID 2.1



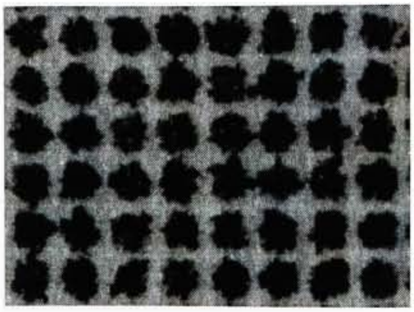
10 x 10, 105 µm, SID 2.1



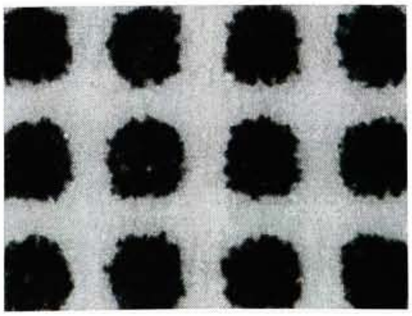
4 x 4, 42 µm, SID 2.1



12 x 12, 126 µm, SID 2.1



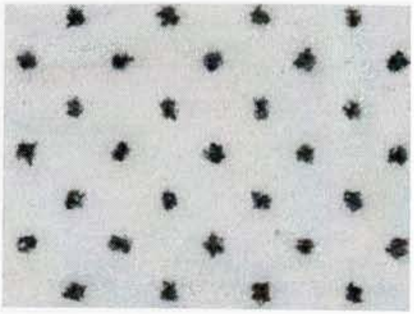
6 x 6, 63 µm, SID 2.1



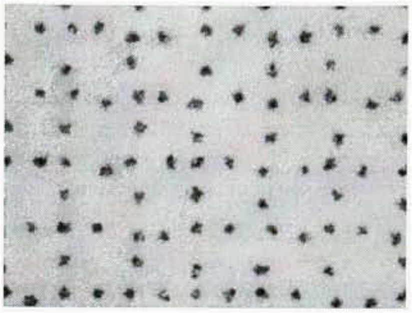
14 x 14, 147 µm , SID 2.1

Images were captured at x5 magnification, Image field of view 1 x 0.75 mm. Stemi SV 11 Microscope Zeiss Germany, Sony 3 CCD Color Video Camera, Model DXC-930P, RasterOps Framegrabber 640 x 480 pixels, Adobe Photoshop 3.0.

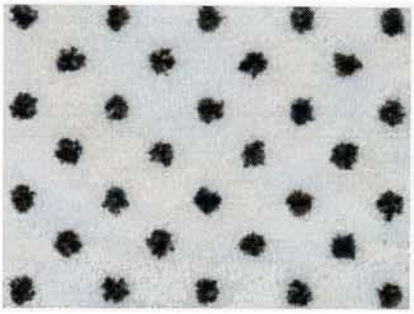
Fig. D.6 CCD captured images of AM and FM tonescales, SID 1.2.



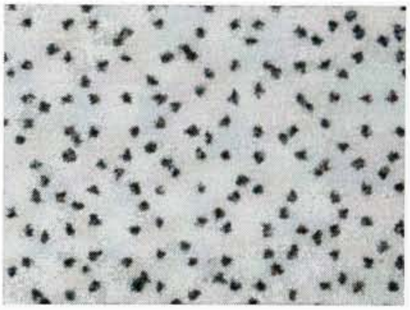
AM tint, Plate dot area 5.5%, SID 1.2



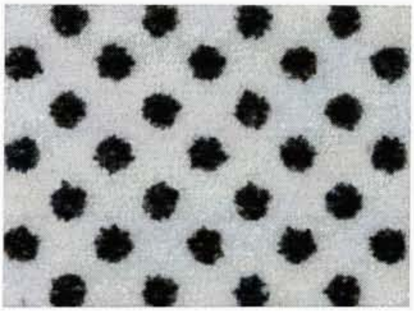
FM tint, Plate dot area 5.7%, SID 1.2



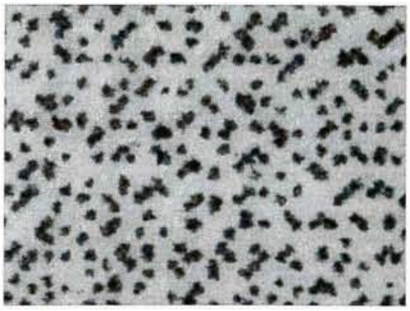
AM tint, Plate dot area 11.7%, SID 1.2



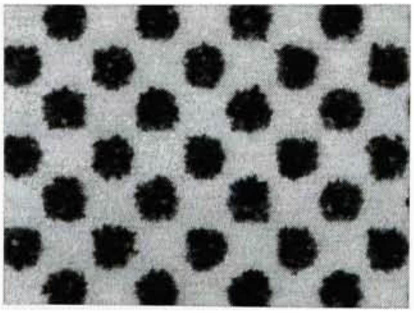
FM tint, Plate dot area 11.1%, SID 1.2



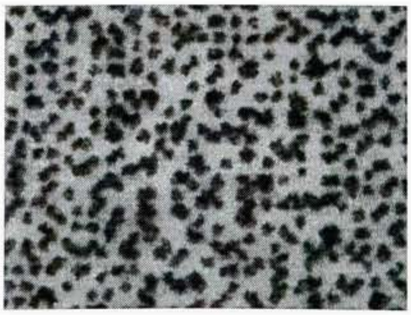
AM tint, Plate dot area 22.7%, SID 1.2



FM tint, Plate dot area 22.3%, SID 1.2



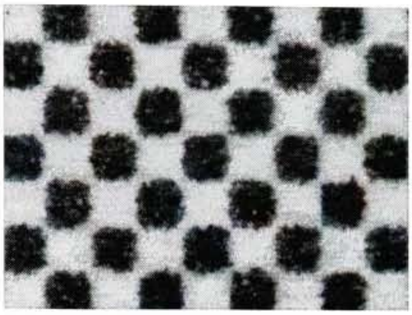
AM tint, Plate dot area 33.9%, SID 1.2



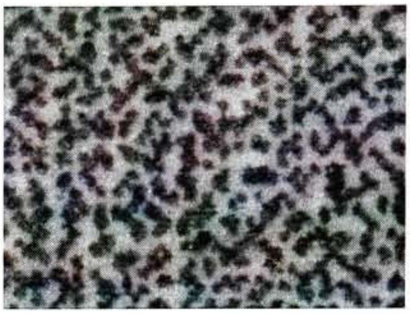
FM tint, Plate dot area 33.5%, SID 1.2

Images were captured at x5 magnification, Image field of view 1 x 0.75 mm. Stemi SV 11 Microscope Zeiss Germany, Sony 3 CCD Color Video Camera, Model DXC-930P, RasterOps Framegrabber 640 x 480 pixels, Adobe Photoshop 3.0.

Fig. D.6(continued) CCD captured images of AM and FM tonescales, SID 1.2

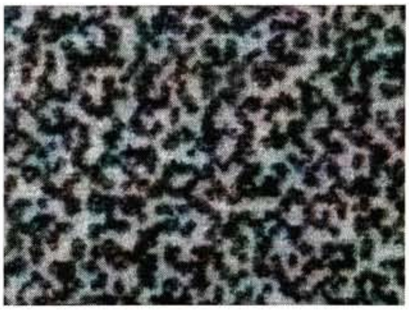


AM tint, Plate dot area 44.6%, SID 1.2

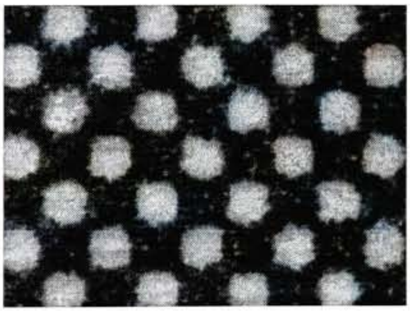


FM tint, Plate dot area 44.2%, SID 1.2

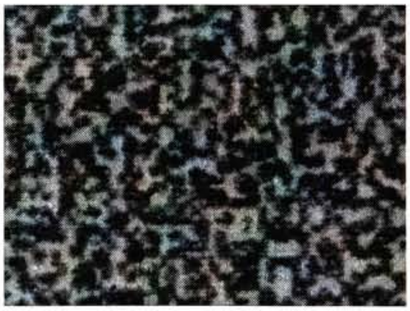
AM tint, Plate dot area 54.5%, SID 1.2



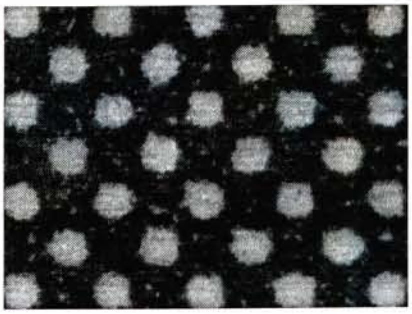
FM tint, Plate dot area 54.1%, SID 1.2



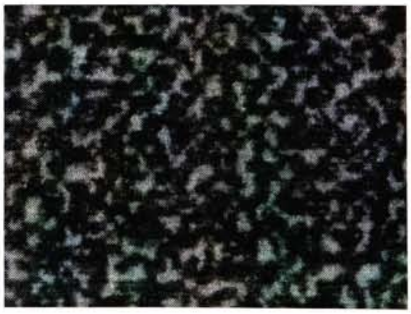
AM tint, Plate dot area 64.5%, SID 1.2



FM tint, Plate dot area 64.0%, SID 1.2



AM tint, Plate dot area 73.7%, SID 1.2



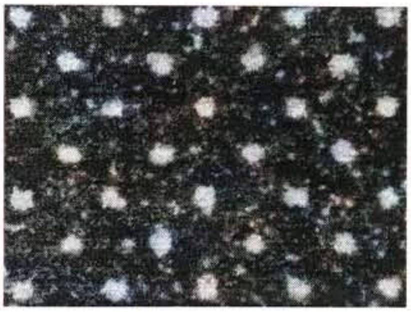
FM tint, Plate dot area 73.2%, SID 1.2

Images were captured at x5 magnification, Image field of view 1 x 0.75 mm. Stemi SV 11 Microscope Zeiss Germany, Sony 3 CCD Color Video Camera, Model DXC-930P, RasterOps Framegrabber 640 x 480 pixels, Adobe Photoshop 3.0.

Fig. D.6(continued) CCD captured images of AM and FM tonescales, SID 1.2

AM tint, Plate dot area 83.4%, SID 1.2

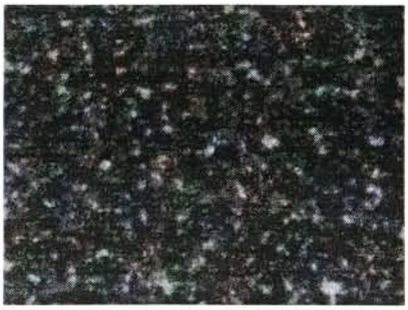
FM tint, Plate dot area 82.6%, SID 1.2



AM tint, Plate dot area 92.0%, SID 1.2

FM tint, Plate dot area 92.0%, SID 1.2

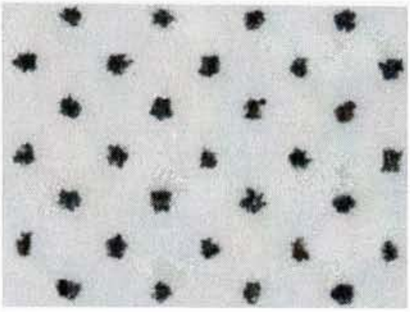
AM tint, Plate dot area 100%, SID 1.2



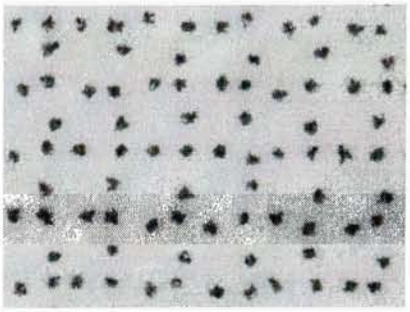
FM tint, Plate dot area 100%, SID 1.2

Images were captured at x5 magnification, Image field of view 1 x 0.75 mm. Stemi SV 11 Microscope Zeiss Germany, Sony 3 CCD Color Video Camera, Model DXC-930P RasterOps Framegrabber 640 x 480 pixels, Adobe Photoshop 3.0.

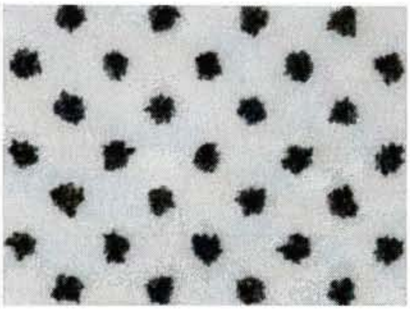
Fig. D.7 CCD captured images of AM and FM tonescales, SID 1.6.



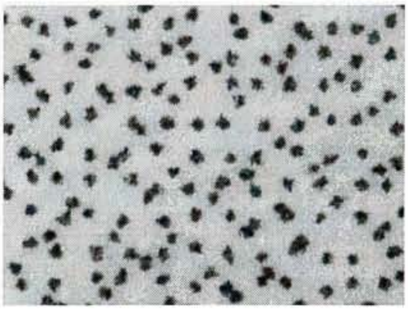
AM tint, Plate dot area 5.5%, SID 1.6



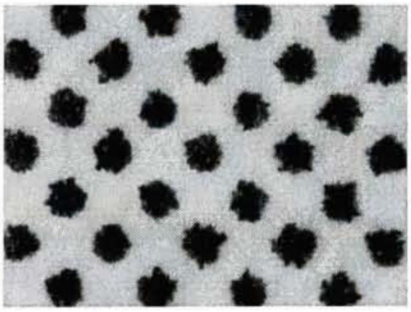
FM tint, Plate dot area 5.7%, SID 1.6



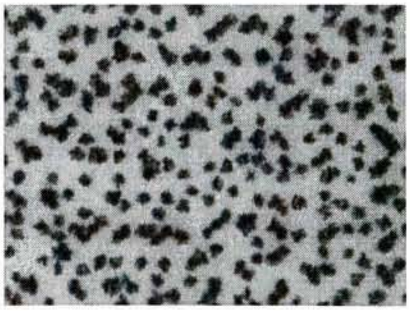
AM tint, Plate dot area 11.7%, SID 1.6



FM tint, Plate dot area 11.1%, SID 1.6

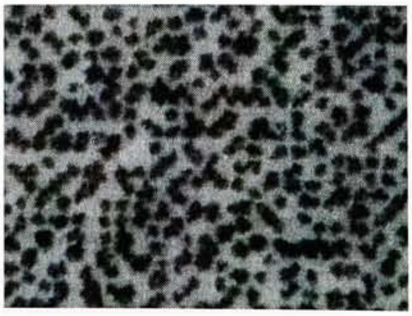


AM tint, Plate dot area 22.7%, SID 1.6



FM tint, Plate dot area 22.3%, SID 1.6

AM tint, Plate dot area 33.9%, SID 1.6

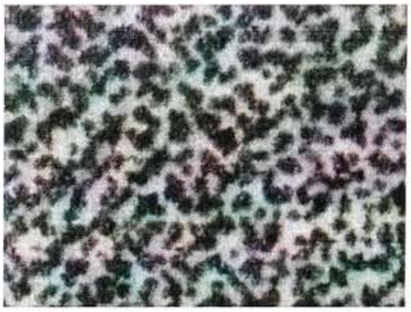


FM tint, Plate dot area 33.5%, SID 1.6

Images were captured at x5 magnification, Image field of view 1 x 0.75 mm. Stemi SV 11 Microscope Zeiss Germany, Sony 3 CCD Color Video Camera, Model DXC-930P, RasterOps Framegrabber 640 x 480 pixels, Adobe Photoshop 3.0.

Fig. D.7(continued) CCD captured images of AM and FM tonescales, SID 1.6

AM tint, Plate dot area 44.6%, SID 1.6

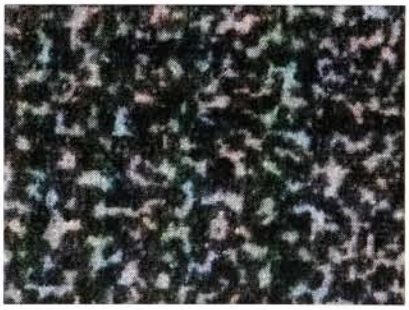


FM tint, Plate dot area 44.2%, SID 1.6

AM tint, Plate dot area 54.5%, SID 1.6

FM tint, Plate dot area 54.1%, SID 1.6

AM tint, Plate dot area 64.5%, SID 1.6



FM tint, Plate dot area 64.0%, SID 1.6

AM tint, Plate dot area 73.7%, SID 1.6

FM tint, Plate dot area 73.2%, SID 1.6

Images were captured at x5 magnification, Image field of view 1 x 0.75 mm. Stemi SV 11 Microscope Zeiss Germany, Sony 3 CCD Color Video Camera, Model DXC-930P, RasterOps Framegrabber 640 x 480 pixels, Adobe Photoshop 3.0.

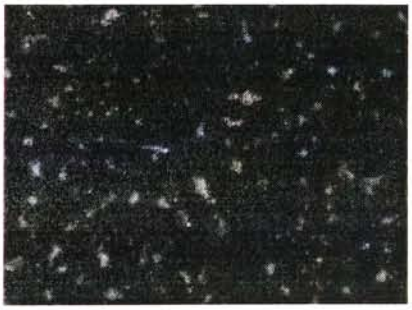
Fig. D.7(continued) CCD captured images of AM and FM tonescales, SID 1.6

AM tint, Plate dot area 83.4%, SID 1.6

FM tint, Plate dot area 82.6%, SID 1.6

AM tint, Plate dot area 92.0%, SID 1.6

FM tint, Plate dot area 92.0%, SID 1.6

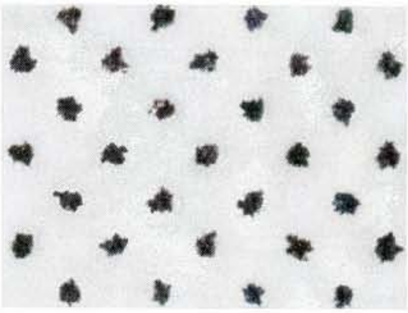


AM tint, Plate dot area 100%, SID 1.6

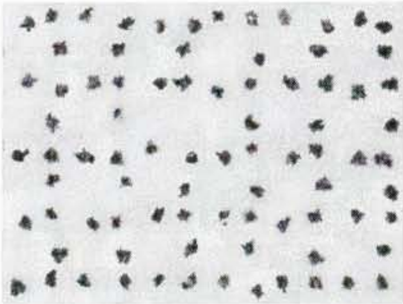
FM tint, Plate dot area 100%, SID 1.6

Images were captured at x5 magnification, Image field of view 1 x 0.75 mm. Stemi SV 11 Microscope Zeiss Germany, Sony 3 CCD Color Video Camera, Model DXC-930P, RasterOps Framegrabber 640 x 480 pixels, Adobe Photoshop 3.0.

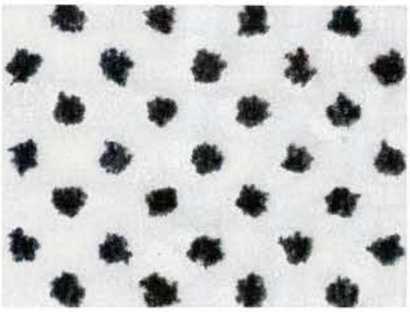
Fig. D.8 CCD captured images of AM and FM tonescales, SID 1.9.



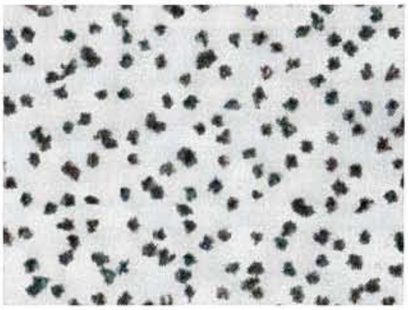
AM tint, Plate dot area 5.5%, SID 1.9



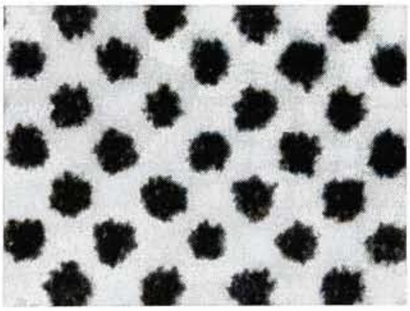
FM tint, Plate dot area 5.7%, SID 1.9



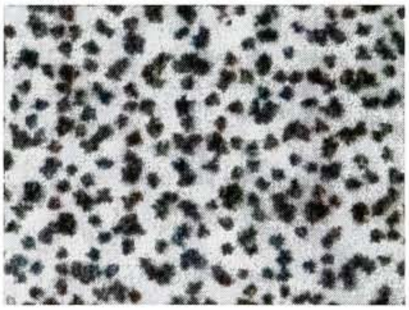
AM tint, Plate dot area 11.7%, SID 1.9



FM tint, Plate dot area 11.1%, SID 1.9



AM tint, Plate dot area 22.7%, SID 1.9



FM tint, Plate dot area 22.3%, SID 1.9

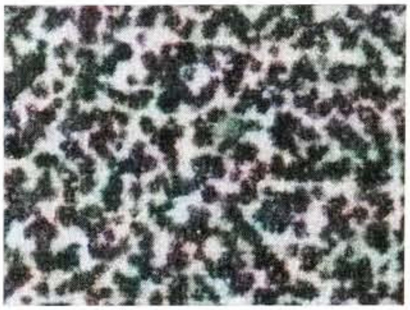
AM tint, Plate dot area 33.9%, SID 1.9

FM tint, Plate dot area 33.5%, SID 1.9

Images were captured at x5 magnification, Image field of view 1 x 0.75 mm. Stemi SV 11 Microscope Zeiss Germany, Sony 3 CCD Color Video Camera, Model DXC-930P, RasterOps Framegrabber 640 x 480 pixels, Adobe Photoshop 3.0.

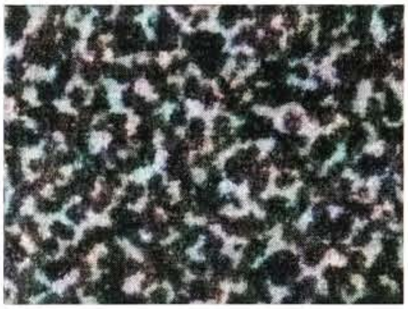
Fig. D.8(continued) CCD captured images of AM and FM tonescales, SID 1.9

AM tint, Plate dot area 44.6%, SID 1.9



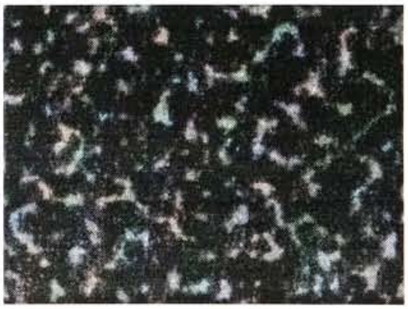
FM tint, Plate dot area 44.2%, SID 1.9

AM tint, Plate dot area 54.5%, SID 1.9



FM tint, Plate dot area 54.1%, SID 1.9

AM tint, Plate dot area 64.5%, SID 1.9



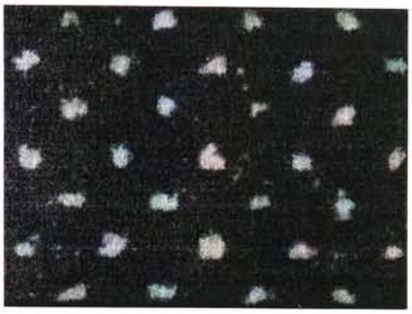
FM tint, Plate dot area 64.0%, SID 1.9

AM tint, Plate dot area 73.7%, SID 1.9

FM tint, Plate dot area 73.2%, SID 1.9

Images were captured at x5 magnification, Image field of view 1 x 0.75 mm, Stemi SV 11 Microscope Zeiss Germany, Sony 3 CCD Color Video Camera, Model DXC-930P, RasterOps Framegrabber 640 x 480 pixels, Adobe Photoshop 3.0.

Fig. D.8(continued) CCD captured images of AM and FM tonescales, SID 1.9



AM tint, Plate dot area 83.4%, SID 1.9

FM tint, Plate dot area 82.6%, SID 1.9

AM tint, Plate dot area 92.0%, SID 1.9

FM tint, Plate dot area 92.0%, SID 1.9

AM tint, Plate dot area 100%, SID 1.9

FM tint, Plate dot area 100%, SID 1.9

Images were captured at x5 magnification, Image field of view 1 x 0.75 mm. Stemi SV 11 Microscope Zeiss Germany, Sony 3 CCD Color Video Camera, Model DXC-930P, RasterOps Framegrabber 640 x 480 pixels, Adobe Photoshop 3.0.

Appendix E

Line traces across 32 μm halftone dots with an Atomic force microscope.

E. Line traces across 32 μm halftone dots with Atomic force microscope.

Figure E.1 shows linetraces across 32 μm halftone dots printed at SID 1.2. The first line (top) is drawn between the halftone dots. The second and third lines are drawn across the halftone dots. The third line is drawn closest to the center of the halftone dots.

Due to the roughness of the substrate it is not possible to detect a difference in height between the inked and non-inked areas. However, a difference in roughness can be detected. As seen in Fig. E.1 the lines across the dots are smoother than the line drawn between the dots.

Fig. E.1 Line traces across 32 μm dot, SID 1.2, atomic force microscope.

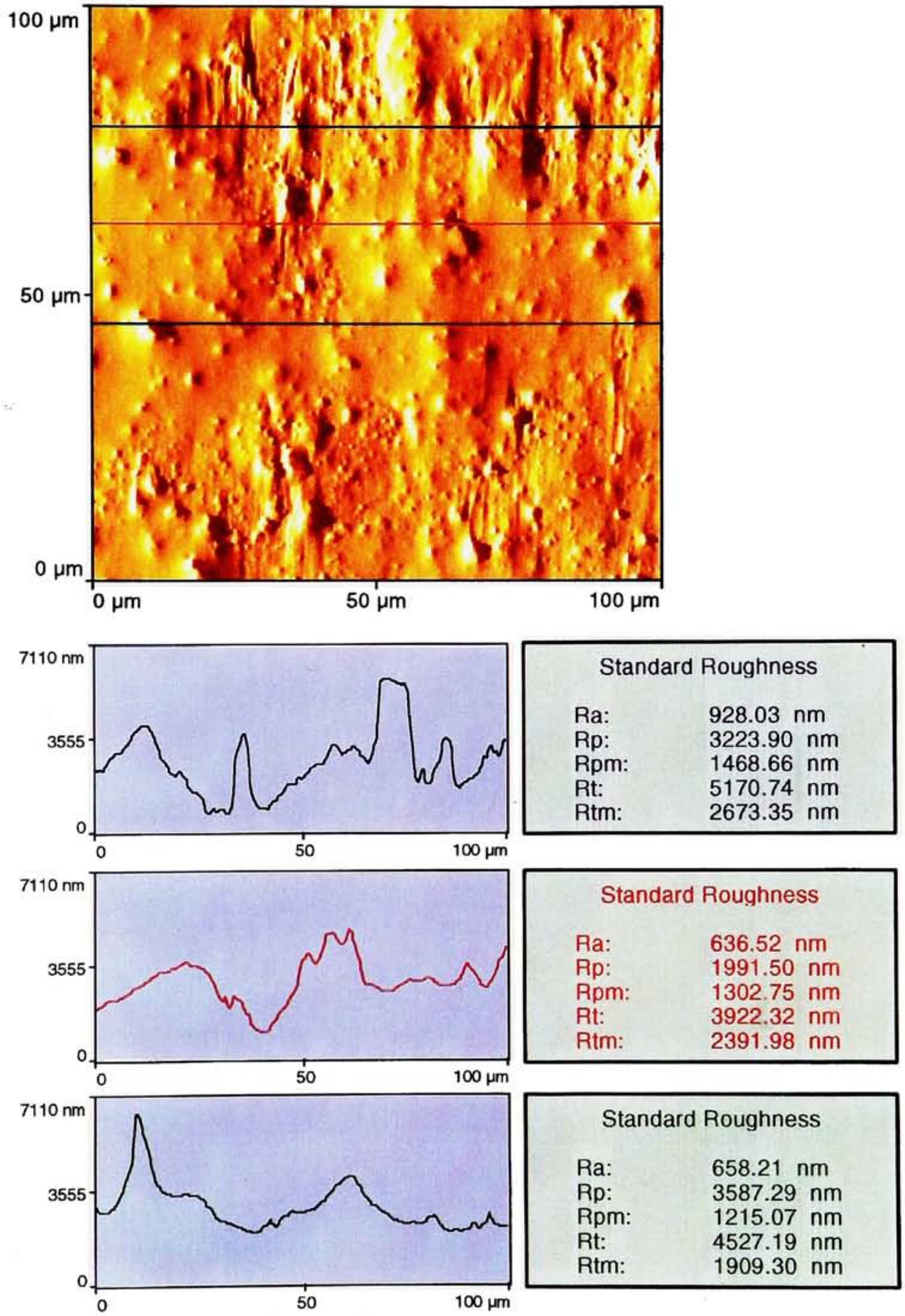


Fig. E.1 Line traces across 32 μm dot, SID 1.2. Atomic Force microscope, Topometrix system serial # 1195-004.